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Aquila fasciata (Vieillot, 1822) and *Corvus monedula* (Linnaeus, 1758) - Italy, southern Sicily

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Bonelli's Eagle, *Aquila fasciata* (Vieillot, 1822) (Accipitriformes Accipitridae).

It is a polytypic species with a Palearctic-tropical distribution with two subspecies. It is widespread in northern Africa, in Mediterranean Europe, southern Asia and some islands of Oceania. Almost all of the Italian population lives in Sicily, as it is very rare in Sardinia and sporadic in Calabria. It inhabits extensive agricultural areas, arable land and pastures, shrubs and the Mediterranean scrub with walls and rocky environments where it nests. It is a species protected by law 157/92 (Rules for the protection of wildlife and homeotherms and for hunting). It is included: in the SPEC3 list (populations concentrated in Europe, with an unfavorable conservation status); in attachment 1 of the Birds Directive CE79/409, amended with CE2009/147; in the Red List of Breeding Birds in Italy, category EN (endangered). The Sicilian population, in the 70s of the last century, is made by 40 couples. In 2000, a population of 13 couples was registered, in 2013, of 33 couples, of which 7 territorial, and finally, in 2017, there were 44 couples. Recent surveys carried out in Sicily in the province of Caltanissetta and adjacent territories have confirmed the positive growth trend found in Sicily and recorded a population of 20 couples with a density of 255 sq km/couples. In the province of Caltanissetta alone, it went from 5 couples in 2004 to 9 in 2017. In 21 nestings, from 2012 to 2017, fledglings were recorded from the first week of May to the second of June. The species is threatened by poaching, habitat changes and the ever more invasive human presence in the breeding and feeding areas.

Rosario Mascara. Via Popolo 6, 93015 Niscemi, Caltanissetta, Italia; e-mail: wmasca@tin.it (photos R. Mascara).



Aquila fasciata adult (above) and young specimen (below). Southern Sicily (Italy).

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Estimating biodiversity through extrapolation: a better function

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ABSTRACT A more general hyperbolic function is proposed for interpolating the number of accumulated species when observations are extended to long time intervals. The suggested function take also in account the insects phenology and the rate in the species accumulation number.

KEY WORDS Extrapolation, Biodiversity; Hymenoptera; Mutillidae; Chrysididae; Gasteruptionidae; Apoidea.

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INTRODUCTION

When the species richness is sampled and investigated by means of any kind of traps, visual collection or literature study, the accumulated number of observed species increase monotonically as a function of investigation efforts. The number of accumulated species, (Number Accumulated Species NAS: $S(x)$) is expected to approach an asymptotic value corresponding to the extrapolated number (S_m) of species present in the studied biotope during the investigation time interval.

To estimate S_m , we need to interpolate the $S(x)$ data as a function of sampling numbers: from the initial value of 0 for $x=0$ (no sampling) to the asymptotic value S_m . To perform interpolation we need a function with a convenient shape to represent the time evolution of biodiversity. The function is adjusted to experimental data by the a set of parameters: $S(x) = f(x, A, B, C, \dots)$. The parameters are real numbers to be calculated from regression.

Unfortunately, the number of available sample data $S(x)$ is usually limited by constraints on available time for fieldwork: therefore, the function $S(x)$

must be carefully selected in order to have the right properties, including a fast asymptotic convergence and a minimum number of parameters.

The choice of the function may follows from the solution of a differential equation describing the population dynamic. In any case, the function $S(x)$ must be monotonic, increasing from zero (no sampling) to the asymptotic value S_m . It is worth to note that NAS is not symmetrical in time. There is a difference between past and future. Considering long time intervals the extinction of one species do not decrease the NAS, while the observation of a new species, truly new or occasional visitor, increases the NAS and the asymptotic value. This asymmetry is not present when the richness is estimated from the Lognormal distribution (Magurran 1995). In fact, the Lognormal distribution estimates only the number of species present during the time interval used to perform samplings.

In seminal papers Colwell & Coddington (1994) and Colwell et al. (2004) discussed the biodiversity evaluation through extrapolation. Colwell & Coddington suggested to interpolate the $S(x)$ data to an Hyperbolic function (the well known Michaelis-Menten function):

$$1) S(x) = x/(K+x) S_m$$

where S_m is the estimated species number and K a constant (the number of samplings needed to observe $S_m/2$).

Function 1) increases monotonically from zero to S_m . On the contrary, the derivate of function 1) decreases monotonically from a maximum (for $x=0$) to zero for large x values (Fig. 1).

Thus, the above eq.1) cannot take in account possible changes in the rate of new records accumulation following from fluctuations in phenology. Of course this is not adequate when the sampling is performed all year around. In fact, a convenient and practical protocol to perform samplings is to capture specimens continuously for at least (possibly) one full year, especially if traps are positioned on sites not easy to be visited, such as isolate islands or dangerous countries, or when special permits are required.

It is well known that the individuals emergence rate is variable and reach its maximum in spring (at least in Palaearctic climate), depending on the species-group and influenced by seasonal fluctuations in temperature, humidity, etc. For practical reasons, at least in Palaearctic region, is convenient to continuously operate traps from early spring to late fall. In such a case, it is well known that the species emergence begins slowly and reaches its maximum in June-July, then significantly decreases from July-August, especially in the case of hot and dry summers as in mediterranean sites. This heuristically suggests the need of a simple hyperbolic function, with a derivate not monotonic. We suggest a generalized hyperbolic function as:

$$2) S(x) = x^n/(K+x^n) S_m$$

where “ n ” is an additional constant and a real positive number. When $n>1$, eq. 2) has the needed inflexion point (a derivative maximum) and, in addition, approaches faster the asymptotic value S_m (Fig. 2). This is also an additional favorable property because in a year interval, the samplings number may be reduced due to constraints in operating the trap, possibly in remote locations or not easy to be visited (Fig. 3).

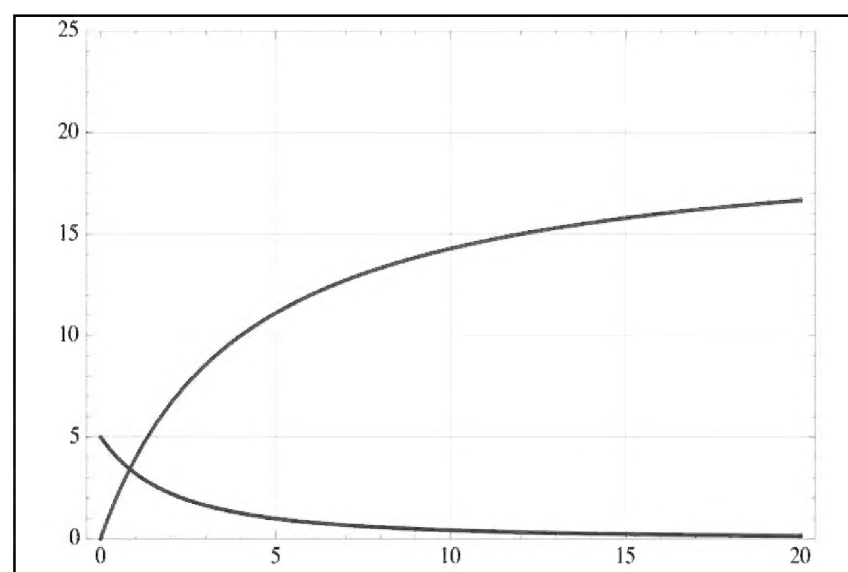


Figure 1. Plot of the Michaelis-Menten function for $S_m=20$ (red line) or of its derivative (blue line). Note the slow approach to the asymptotic value of 20.

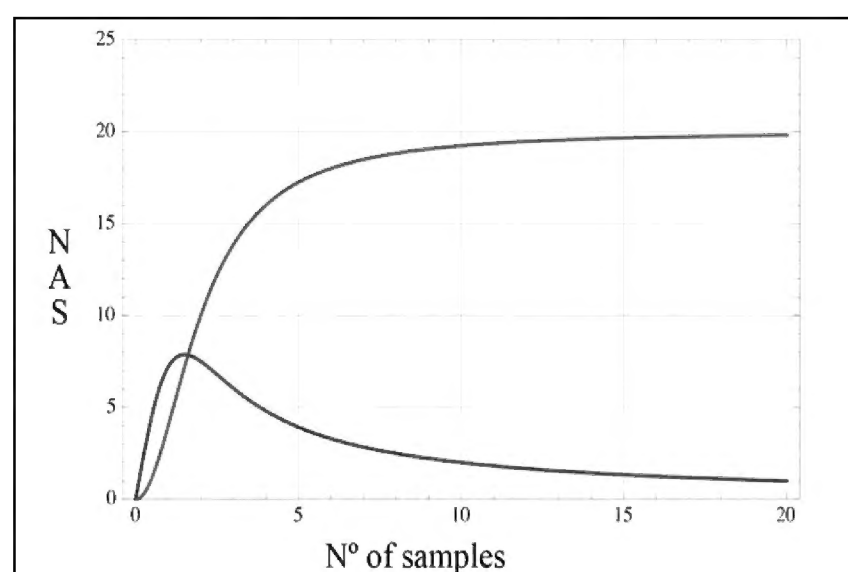


Figure 2. Plot of the generalized hyperbolic function (eq.2) (red line) and of its derivative (blue line) for $S_m=20$ and $n=2$. Note the faster approach to the asymptotic value. The derivative is 0 for $x=0$, and it reaches a maximum and then decreases monotonically to zero.

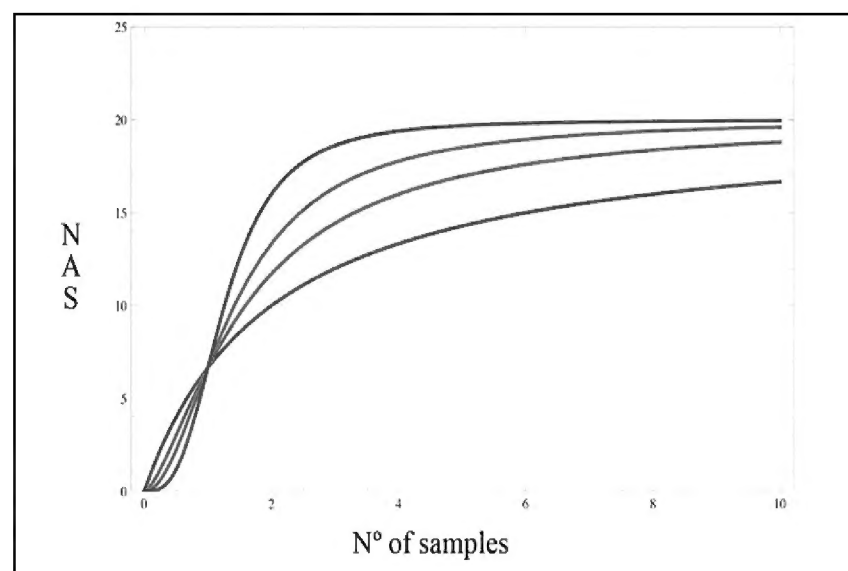


Figure 3. Plot of eq. 2). for four n values, from bottom to top: $n=1, 1.5, 2$ and 3 respectively. The asymptotic value is fixed at $S_m=20$. For $n=3$ the asymptote is reasonably approached after only 4 to 6 samples.

EXPERIMENTAL RESULTS

Some examples are discussed to illustrate the better interpolations available from eq.2), when the constant n is let free to better adjust the function to the experimental data. When the experimental points are too few the interpolation with eq.2) (three free parameters instead of two) may become inadequate and the calculated S_m value becomes unstable. In such a case, a better and easier interpolation can be obtained by fixing n to have any value in the range $1.5 < n < 2.5$, thus reducing the free parameters to two. In such a case, a good extrapolation is always available, as it will be shown. In the following examples, the non-linear interpolation is calculated with the fast converging Marquardt method and commercial software.

In recent years, a number of Malaise traps operated in Tuscany, Sardinia, Sicily, Piedmont and small Tyrrhenian islands in order to investigate Hymenoptera biodiversity. Major evidence was given to Aculeate Hymenoptera, mainly for the relevance as impollinators (Abrol, 2012).

In 2016, two Malaise traps were positioned in the Monterufoli-Caselli Nature Reserve in southern Pisa Province ("Colline metallifere" Tuscany), in order to investigate the influence of a humid zone on entomocoenosis (Strumia et al., 2017). The trap captured continuously from April 28th to September 8th and the material was sorted and identified in nine samples. The observed number of the accumulated species of Hymenoptera Mutillidae is shown in figure 4, together with the best interpolations available from eqs.2 and 1, respectively. The predicted asymptotic values are respectively $16 < S_m = 18 < 19$ (95% confidence interval, $n = 2.83$) and $12 < S = 33 < 54$ with the Michaelis-Menten function ($n = 1$, 95% confidence interval, $n = 1$). Not only the interpolation with the Michaelis-Menten function is clearly unable to properly interpolate the experimental data, but the predicted richness is too large and in disagreement with the results already observed in Tuscany (Strumia, 2007; Strumia & Pagliano, 2007).

In the same site, the species of Hymenoptera Gasteruptiidae were also counted. The interpolated data gives a similar result as shown in figure 5. The calculated S_m values are respectively $S_m = 19 \pm 6$ ($n = 1$) and $S_m = 14 \pm 1$ ($n = 4$). In Italy, only 20 species of Gasteruptiidae are known (Pagliano & Scaramozzino, 2000), thus the prediction with

the Michaelis-Menten function is unreasonable. On the contrary, the interpolation with eq.2 is inside the acceptable range and shows that the Caselli reserve hosts a rich Gasteruptiidae biodiversity, as already observed for others insects

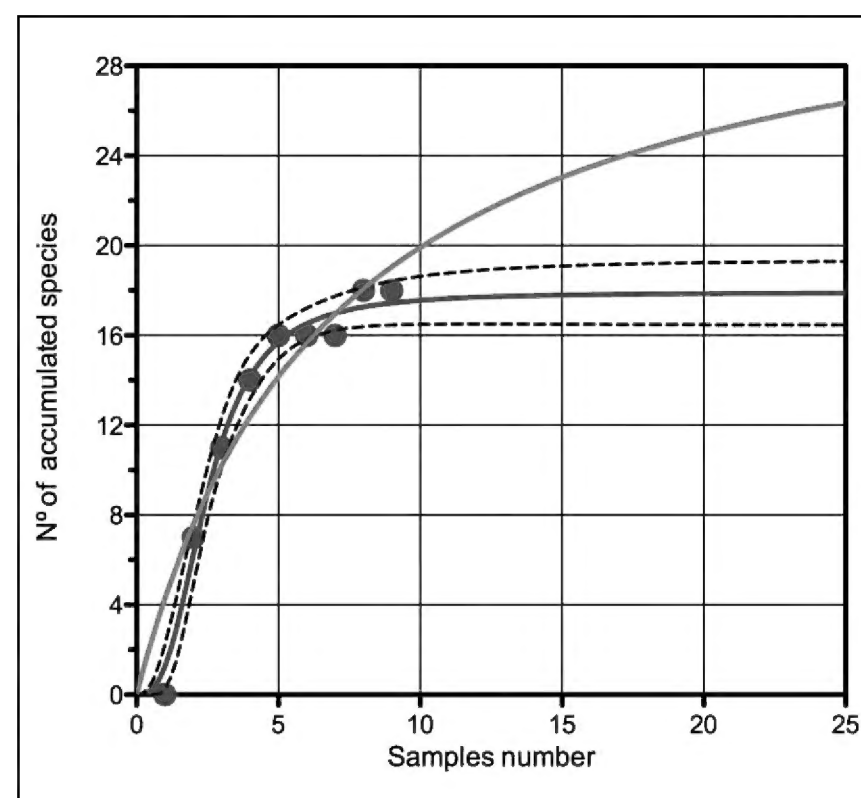


Figure 4 . Number of Mutillidae species captured in the "Caselli Nature Reserve" in 2016 by Malaise traps; the blue line shows the best interpolation from eq.2 and the red line the best interpolation from eq.1; the broken lines show the 90% confidence range of eq.2; eq. 1 is clearly unable to properly interpolate the experimental data.

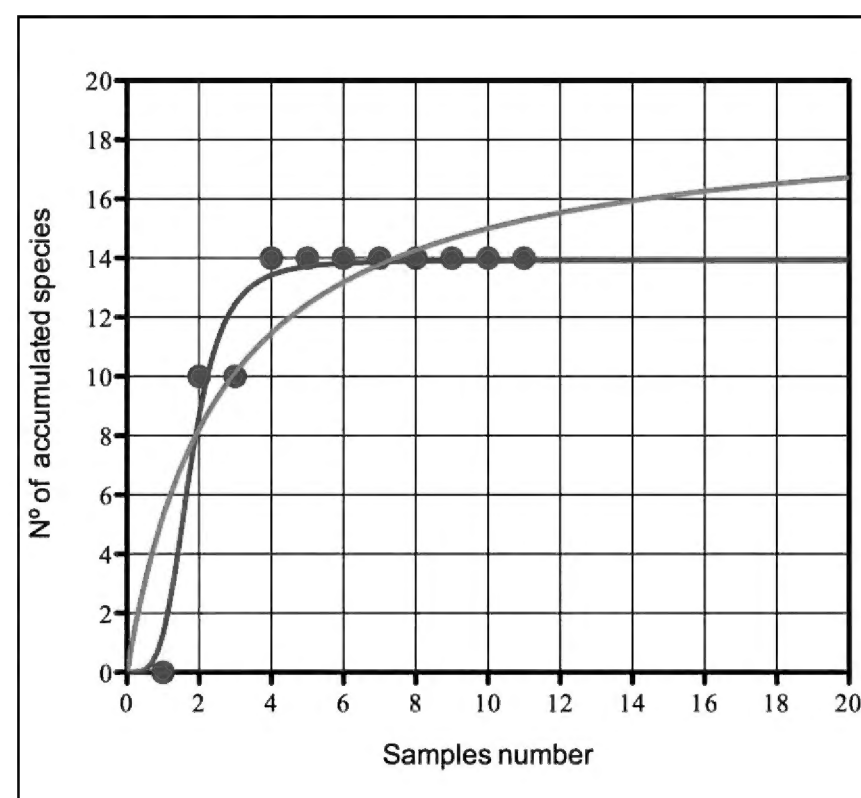


Figure 5. Number of the accumulated Gasteruptiidae species observed in the "Caselli Nature Reserve" in 2016 and captured by a Malaise trap (blue dots); blue line shows the best interpolation with eq.2; red line those with eq.1.

groups: Apoidea, Chrysididae, Pompilidae (Filippi & Strumia, 2018).

Malaise traps operated in the “San Rossore Nature Reserve” near Pisa town. San Rossore extends along the Mediterranean coast and has several humid and wooded zones on the back of coastal sand dunes. These sites are favorable for sand nesting insects. From the captures of 2015 we studied the Mutillidae wasps obtaining a similar result as Gasteruptiidae (Fig. 6). In this case, a larger number of sampling data is available and the interpolations is done with $n=1$ and $n=3$ respectively. For $n=3$ a good interpolation is obtained ($R^2 = 0.98$). The richness prediction is in agreement with the more recent and repeated observations of Mutillidae around Pisa (Strumia, 2007). On the contrary, the result from the Michaelis-Menten function ($n=1$) badly fits data and give an unreasonable large value for the local richness: $14 < S_m = 27 < 42$ (95% confidence intervals).

In 2002, a Malaise trap operated into “Nebrodi Nature Reserve”, Sicily (Galati Mamertino, 38.01°N, 14.47°E, 950 m. a.s.l.). Hymenoptera Chrysididae were captured in 8 times intervals and the results from the interpolation with eqs. 1 and 2 are shown in figure 7. The result is similar to that of Mutillidae and Gasteruptiidae. The predicted Chrysididae richness is $S_m = 17$ (± 2 species, 95% confidence interval). Again, the interpolation with eq.1 is inadequate.

In previous examples, Hymenoptera families with a moderate number of species were considered. Now, a more species-rich group is considered: the superfamily Apoidea of the Hymenoptera (about 1800 species in Italy: Pagliano 1994). More than 140 species of Apoidea were captured in 2017 in “Caselli Nature Reserve” by a Malaise trap. The Apoidea NAS interpolation is shown by using the functions 1 and 2 respectively (Fig. 8). Apparently, the differences are small, but the numerical results shown in Table 1 demonstrates the better accuracy available from function two (for R^2 index and the “Absolute sum of squares”).

MULTIPLE YEARS DATA COMBINATION

In favorable conditions is possible to repeat the observations for two or more full years. In such a case experimental data can be ordered and combined to obtain a better interpolation from a larger data set.

If all data are combined and ordered following the beginning date of each sampling interval, a larger number of $S(x)$ data points becomes available, and a more accurate interpolation is possible.

This is illustrated in the following study on the Hymenoptera Chrysididae biodiversity in a vineyard of southern Piedmont (north-western Italy).

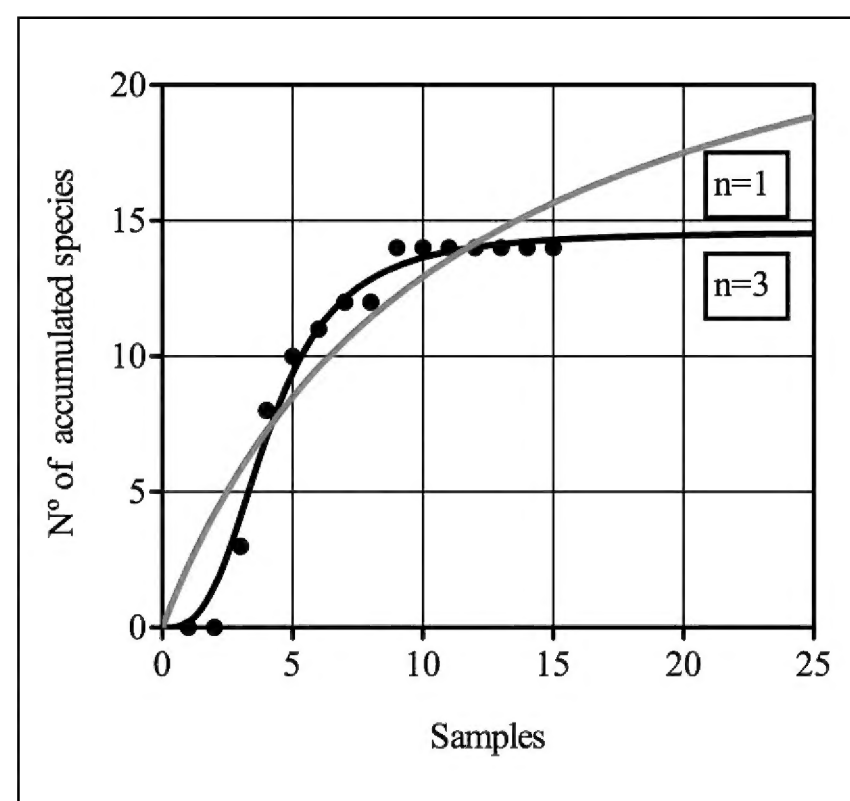


Figure 6. Interpolations of Mutillidae NAS observed in San Rossore Nature Reserve in 2015 (black dots); black line with $n=3$; red line with $n=1$.

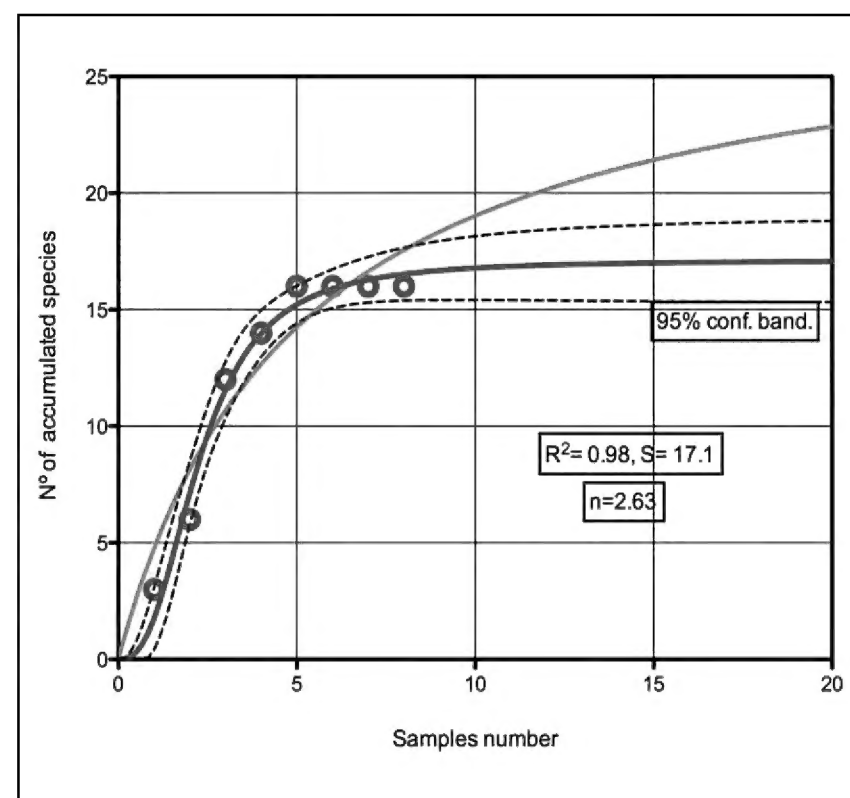


Figure 7. Number of Hymenoptera Chrysididae species captured in Nebrodi Nature Reserve in 2002; blue line interpolation from eq.2; red line interpolation from eq.1; broken lines show the 90% confidence range from eq.2 ($S_m = 17 \pm 2$ species).

In 2016 and 2017, the Pisa University operated a Malaise trap in a vineyard near Barbaresco (Cuneo, Piedmont, 170 meters a.s.l., 44°4'26"N, 08°04'26"E). The trap was positioned near the Ecotone between the vineyard and a wood along Tanaro river (Strumia et al., 2018). In 2016 the Malaise trap captured 24 species (132 individuals) of Hymenoptera Chrysidae, operating from May 18th up to October 17th. In 2017, a notable larger number of Chrysidae species was captured (39 species and 216 individuals) between May 13th - October 10th.

The corresponding $S(x)$ data were combined, as proposed, giving a larger number (16). The interpolation of all data is shown in figure 9, both separately for each year and for the combination of the two years. The numerical results, obtained with and without combination of data, are also shown in Table 2.

In the combined NAS, the general shape, with an inflexion point, is retained, as predicted by eq.2). The statistical confidence and also the fit goodness is also improved.

The remarkable difference in the number of captured species (about plus 162% in 2017) by a trap operating in the same position and orientation is unexplained and suggests the need of further observations. Possibly meteorological fluctuations in temperature, humidity, etc. can largely influence the local biodiversity. Only data recording over a longer time span would provide some statistical correlation and inference.

In any case, this result highlights that the biodiversity measure, based on observations on one single year, remains uncertain, even if statistically sound. In fact, the result estimates the local richness for the studied time interval. Only repeated observations and data accumulation would allow to observe long term trends in populations richness.

CONCLUSIONS

From the discussed experimental results, it follows that the simple hyperbolic Michaelis-Menten function does not describe properly the time evolution of observed number of accumulated species (NAS), especially when the measurements are extended to a full year, from spring to autumn. The

use of more or less automated traps, like Malaise traps, is particularly convenient if traps are positioned on sites not easy to be visited, such as isolate islands or dangerous countries, or when special permits are required.

In such cases, the number of available data is likely to be small and an efficient function to per-

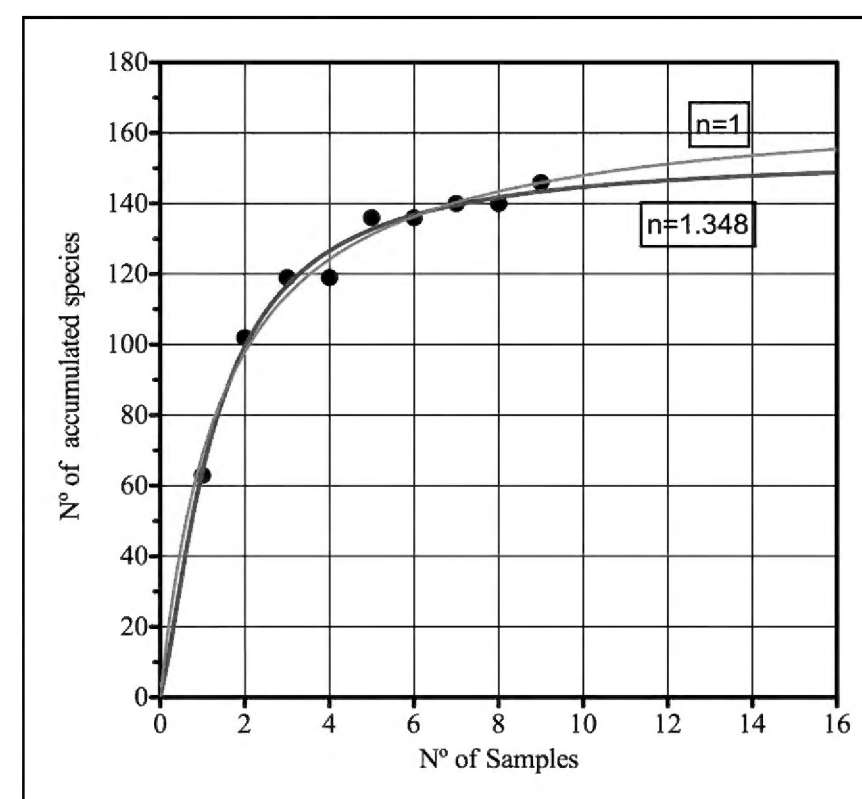


Figure 8. NAS Interpolation of Apoidea speciose group captured in the “Caselli Nature. Reserve” in 2017; red line with eq.1, blue line with eq.2.

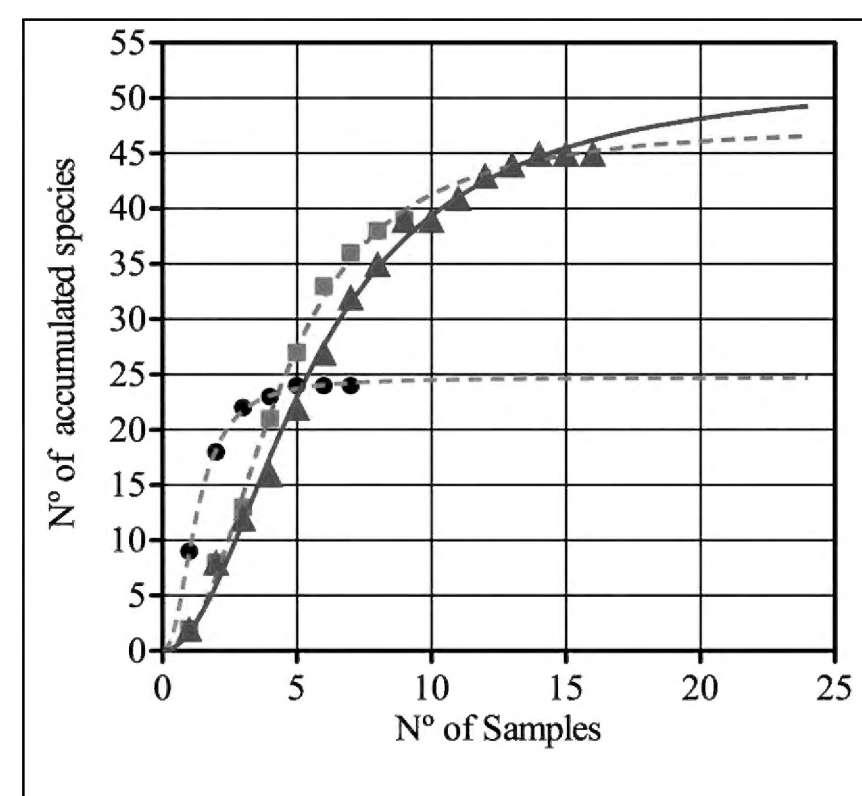


Figure 9. Interpolation of NAS of Hymenoptera Chrysidae captured at Barbaresco (CN) in 2016 (round black dots and red broken line) and in 2017 (pink square dots and pink broken line). The combined $S(x)$ data of 2016 and 2017 are shown in blue (triangular dots and blue line).

Funct. 1 (Michaelis-Menten)		Function 2	
Best-fit values		Best-fit values	
V _m	169.7	V _m	153.8
n	1	n	1.348
K _m	1.465	K _m	1.394
95% Confidence Intervals		95% Confidence Intervals	
V _{max}	158.1 to 181.2	V _{max}	137.4 to 170.1
		n	0.8516 to 1.845
K _m	1.070 to 1.860	K _m	1.064 to 1.723
Goodness of Fit		Goodness of Fit	
R ²	0.9751	R ²	0.9833
Absolute Sum of Squares	137.1	Absolute Sum of Squares	92.21

Table 1. Comparison of interpolation results obtained from functions 1 and 2 for the Hymenoptera Apoidea captured in the “Caselli Nat. Res.” in 2017.

Best-fit values	2016	2017	Combined 2016 and 2017
N° of species predicted	24.72	47.53	52.16
n	2.319	2.282	1.966
K	1.769	29.03	30.11
Std. Error:			
V _m	0.2425	2.767	1.705
n	0.1106	0.2031	0.1255
K	0.08142	5.619	4.841
95% Confidence Intervals			
V _m	24.05 to 25.39	40.76 to 54.30	48.47 to 55.84
n	2.012 to 2.626	1.785 to 2.779	1.695 to 2.237
K _m	1.543 to 1.996	15.28 to 42.78	19.65 to 40.57
Goodness of Fit			
Degrees of Freedom	4	6	13
R ²	0.9984	0.9966	0.9957
Absolute Sum of Squares	0.3019	5.176	13.67
N° of analyzed points	7	9	16

Table 2. Best values from the interpolation, with eq.2, of Chrysididae NAS species number captured at Barbaresco (CN) in 2016 and 2017.

form the statistical interpolation is mandatory. The generalized hyperbolic function as proposed by equation 2 is a more convenient solution when samples are collected during a full year. This is illustrated for locations with Palaearctic climate but it will work properly in any climate with large seasonal fluctuations (monsoon). The suggested function is reliable even if the number of samplings is minimal (five or six).

The number of accumulated species describes an open system where occasional visiting species increase the real richness of the studied site. Large yearly fluctuations have been recently reported for the local estimated richness (as large as 100%). In alternative to the number of accumulated species, we can use two additional and mathematically independent algorithms, namely: the “Lognormal Distribution” and the “Species Area Relationships” (SARS) (Magurran, 1995). These mathematically independent algorithms may provide a crosscheck for results correctness.

All this statistical inference methods give local prediction strongly correlated to the time intervals used to perform the experimental observations. In any case, such count of the species number is essential to observe and study temporal evolution and fluctuations in populations richness.

In some cases, the proposed function, having three free parameters, do not produce a good fit when the available data are too few. In this case, we can obtain an improvement by fixing n to be a number between 2 and 3, thus reducing the free parameters to two.

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Bio-ecological study of hyperparasitoid aphids in the region of Mostaganem (north-western Algeria)

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ABSTRACT

Several species of hyperparasitoids belonging to the subfamilies Charipinae (Hymenoptera: Figitidae) and Pteromalinae (Hymenoptera Pteromalidae) have been identified in the region of Mostaganem (north-western Algeria). Among these species, two of them show a regular presence during the years of study, *Pachyneuron aphidis* (Bouche, 1834) (Pteromalidae), and *Phaenoglyphus villosa* (Hartig, 1841) (Figitidae). These two species have been proved to be effective in adapting very quickly to the environment.

KEY WORDS

Aphids; Algeria, Mostaganem; Charipinae; Pteromalidae.

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INTRODUCTION

Hyperparasitoids are insects that evolve at the expense of primary parasitoids (Sullivan & Völkl, 1999). Within an ecosystem, they occupy the fourth trophic level (Buitenhuis, 2004). The vast majority of hyperparasitoids are hymenoptera, only a few species belong to Diptera and Coleoptera (Gordh, 1981, Sullivan, 1987). They are characterized being small (1 to 2 mm) but robust. Usually, they have a metallic coloration and their antennas have between 8 to 13 antennal segments. Their heads vary from sub-rectangular to oval. Hyperparasitoids are mostly generalists and not likely to depend on the presence of a specific parasitoid (Sullivan & Völkl, 1999). They can act as koïnobionts, meaning that

the female does not kill the host parasitoid at the time of laying the egg and idiobionts. The primary parasitoid is paralyzed or killed during the laying. For example, *Alloxysta* Foerster, 1869 is koïnobiont, while *Asaphes* Walker, 1834 is idiobiont (Sullivan, 1987).

Aphid hyperparasitoids can be classified into two categories according to their mode of development (Stary, 1970; Sullivan, 1987). There are endo-parasitoids and ecto-parasitoids. In the first category, the female lays the egg inside the primary parasitoid, while the aphid continues to live there. Once the aphid is ousted by the primary parasitoid and the mummy is formed, the egg of the hyper-parasitoid hatches and its larva feeds from the primary parasitoid pupa. In this group, there

are hyperparasitoids belonging to the genus *Alloxysta* (Sullivan, 1987). The second category includes ecto-hyperparasitoids. Two elements distinguish the latter from the first group: the female attacks the mummy, which she pierces with her ovipositor and deposits an egg in the larva of the developing primary parasitoid. The egg hatches and the secondary larva feeds on the tissues of the primary parasitoid. This is the case of hyperparasitoids of the genus *Asaphes*, *Dendrocercus* Ratzeburg, 1852 and *Coruna* Walker, 1833 (Sullivan, 1987). The life cycle of hyperparasitoids is often related to the nutritional quality of the host. Most hyperparasitoids attack their host before mummification of the aphid for maximum benefit (Buitenhuis, 2004). These species attack either the larva of the parasitoid in the aphid before it is killed, or the parasitoid pupa or pupa in the aphid mummy (Buitenhuis, 2004).

In this study, the approach is based on a thorough knowledge of the population dynamics of the hyperparasitoid fauna, on the knowledge of the bioecological parameters intervening in the regulation of the hyperparasitoid populations, with an assessment of the impact of different abiotic factors (temperature in this case) on the biotic regulation of hyperparasitoid populations

MATERIAL AND METHODS

In this study the hyperparasitoid aphid has been found in Mostaganem provinces, north-western Algeria. These regions were chosen due to their important agricultural production in the country by the experimental exploitation of the Department of Agricultural Science at the Mostaganem University.

All the materials have been collected by the first author. The sampling unit used in this experiment is pepper (*Piper nigrum* L.).

The surveys were carried out once a week from January until July of the years from 2011 to 2014. The mummified aphids were separated and placed in microtubes and labeled Petri dishes up to the emergence of adult hyperparasitoids. The adults were identified by two of the authors specialists, Pujade-Villar and Ferrer-Suay (University of Barcelona, Spain).

The rate of hyperparasitism corresponds to the ratio number of hyperparasitoids counted on the

total number of parasitoids emerged (primary and secondary) times 100.

RESULTS

Of the two groups of hyperparasitoids recorded in this study, one belongs to family Figitidae (Cynipoidea). Here, we distinguish in particular the subfamily of Charipinae. Its members are widely distributed in all biogeographical regions (Ferrer-Suay et al., 2015). They are divided among 8 genera, namely: *Alloxysta* Forster, 1869 (cosmopolitan) *Phaenoglyphis* Forster, 1869 (cosmopolitan) *Lytoxysta* Kieffer, 1909 (North America), *Lobopteracharips* Paretas-Martinez & Pujade-Villar, 2007 (Nepal), *Dilyta* Forster, 1869, *Apocharips* Fergusson, 1986 (East Palearctic and the Neotropics), *Dilapothor* Paretas-Martinez & Pujade-Villar, 2006 (Australia) and *Thoreauana* Girault, 1930 (Australia). *Alloxysta* and *Phaenoglyphis* are known as hyperparasitoids of aphids via Aphidiinae (Ichneumonoidea: Braconidae) and Aphelininae (Chalcidoidea: Aphelinidae) (Rabasse & Dedryver, 1983; Menke & Evenhuis, 1991).

The results of specimen identifications show hyperparasitoids that live at the expense of primary aphid parasites attacking several cultivated and herbaceous plants in western Algeria (Ferrer-Suay et al., 2015). Hymenoptera species belonging to Charipinae and Pteromalidae found in the study area are either secondary parasitoids or hyperparasitoids (Stary, 1970; Muller et al., 1999).

We recorded the presence of hyperparasitoids from March of every year of this study. Their manifestation has progressed over time. This evolution reaches the maximum rate during the month of May for two successive years (2012 and 2013) (Fig. 1). However, during the last year of observation (2014), we noticed a rapid and early increase in hyperparasitoids beginning in April. These rates of hyperparasitism were higher than in previous years. From May onwards, the rate of hyperparasitism decreases to a very low rate during the month of June, which vanishes towards the beginning of July (Fig. 1).

Under experimental conditions, aphid hyperparasitoids may live longer than 2 months depending on species, with a shorter longevity of males than females. In the laboratory, depending on the

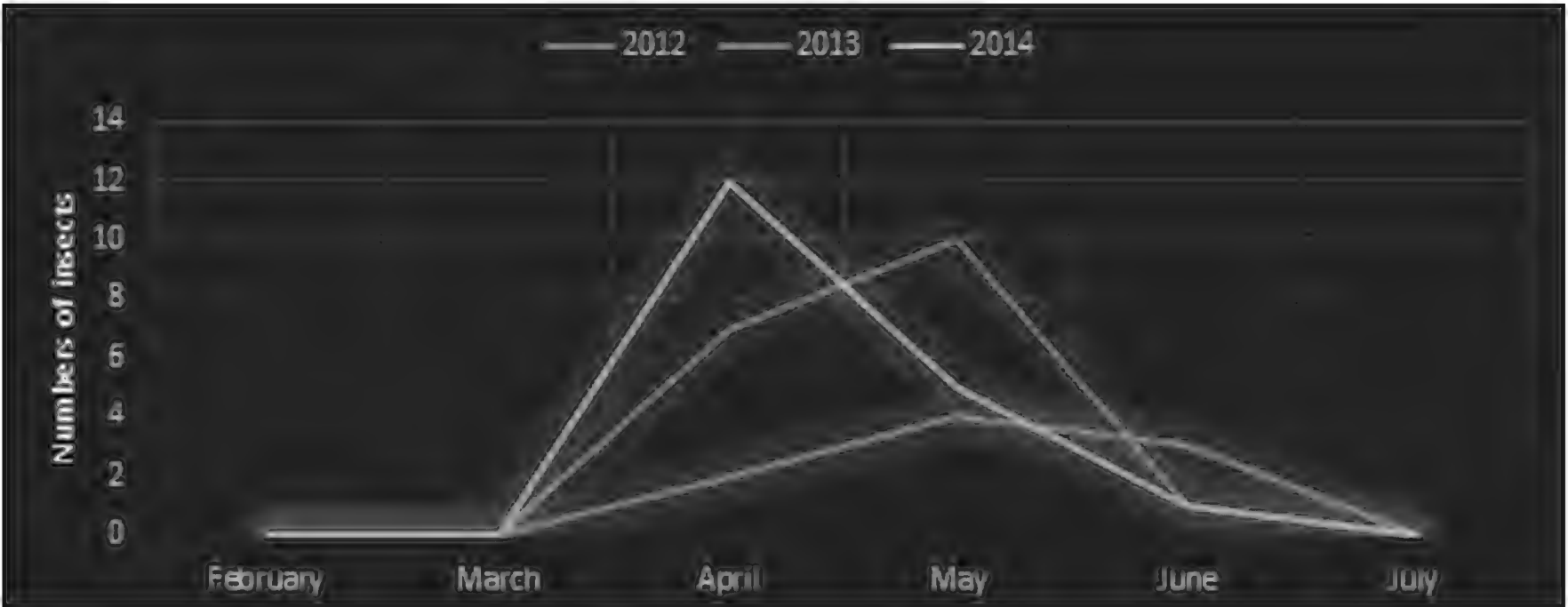


Figure 1. Parasitism rate of parasitoids by hyperparasitoids during the study period (2012/2014).

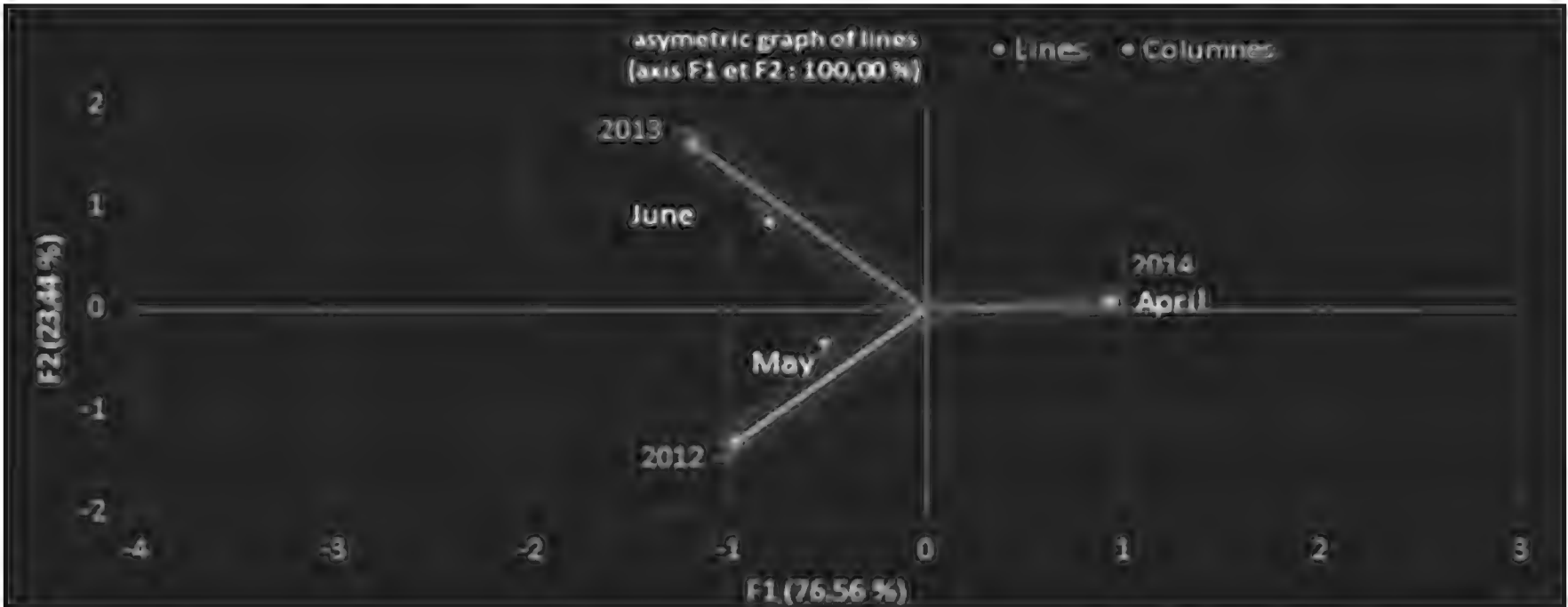


Figure 2. Representation of hyperparasitism in the plan of A.F.C between 2012/2014 (annual effect).

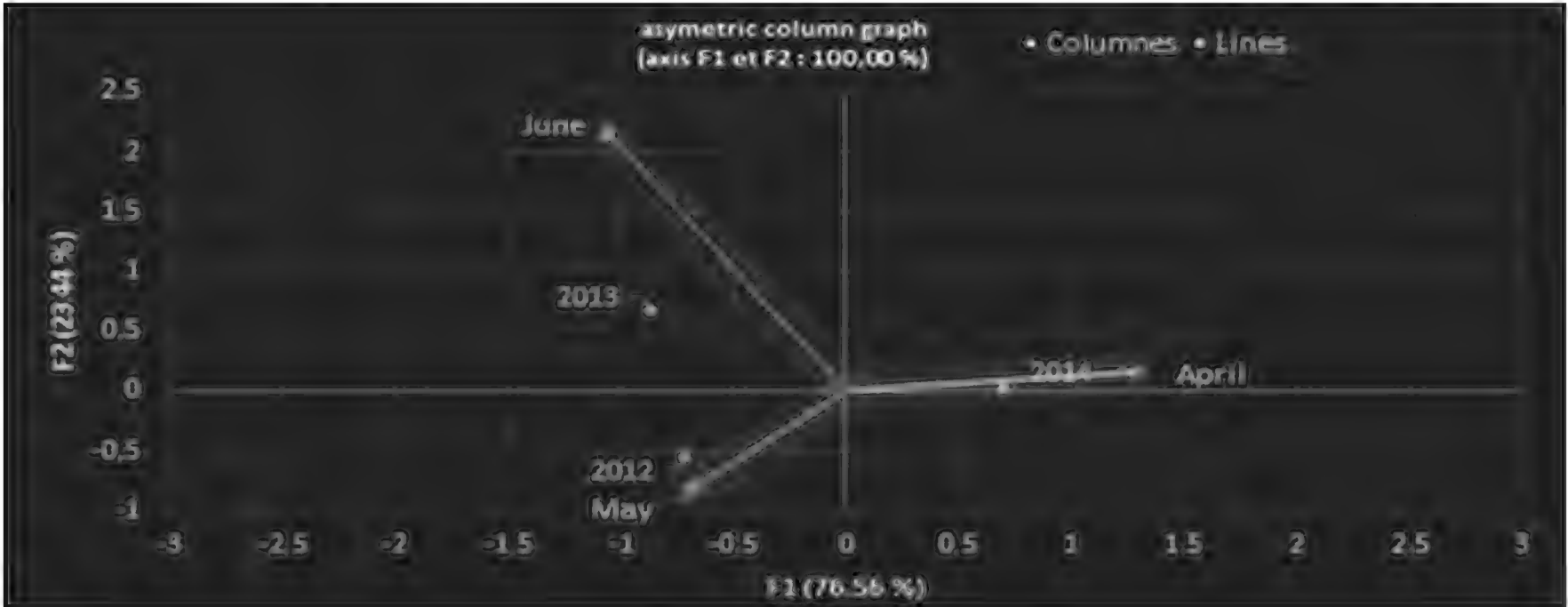


Figure 3. Monthly representation of hyperparasitism in the plan of A.F.C between 2012/2014 (monthly effect).

species, the aphid mummifies about 8 days after the emergence of the primary parasitoid. Two and a half to three days after the mummification of the aphid, the larva of the hyperparasitoid begins to devour the primary parasitoid from which it eventually emerges. It will continue to feed on its remains and eventually emerge from the mummy a few days later. Depending on the species, the complete cycle of development of *Alloxysta* lasts between 13 and 20 days. The primary parasitoid stops its development and is transformed into a soft, blackish mass which serves as food for the *Asaphes* larva. About 21 days later, the adult emerges from the mummy (Table 1).

When we compare these results with those described in the literature, it appears that the results are equivalent to or less than those of other studies (Sullivan, 1987; Schooler et al., 1996; Buitenhuis, 2004). The duration of life cycle development is related to climatic conditions (Sullivan, 1987; Buitenhuis, 2004).

Factor analysis of correspondence (AFC) rates of hyperparasitism during 2012/2014

The factor analysis of the correspondences reveals that the peaks of hyperparasitism are recorded during the month of May 2012. However, it is important to note that the rate of manifestation of hyperparasitism recorded during the month of April 2013 is comparable to that of May 2012 (Fig. 2).

The analysis also revealed that the levels of hyper-parasitism recorded maximum values during the months of March, April and May (Fig. 3).

According to our analysis, the level of hyperparasitism is very important during the years of our study with a maximum reached in 2014 (Fig. 3). The same graphs show a close and positive relationship between spring and hyperparasitism. Nevertheless, the months of June and July 2013 have rates of hyperparasitoids lower than those of April and may be significant (Fig. 3).

If we compare the years of study with each other, we note that the rate of hyperparasitism differs from year to year. Indeed, during the years 2012 and 2014 the rates of hyperparasitism evolved, whereas in 2013 the rate of hyperparasitism remained very low. Indeed, the rate of hyperparasitism, for the years 2012 and 2014, exceeded 10%.

This could be explained by the decrease in the abundance of parasitoids during this period. In 2013, the rate of hyperparasitism was only around 4%, which suggests that the action of biotic factors (presence of parasitoids) and abiotic factors (temperature and hygrometry) allowed the appearance of more and more hyperparasitoids.

Like the primary parasitoids, hyperparasitoids were unable to regulate host populations due to low parasitism and negligible effects on *Myzus persicae* populations (Buitenhuis, 2004).

Relative abundance of hyperparasitoids

During the study years, we recorded a relatively high relative abundance of hyperparasitoids. The species *Pachyneuron aphidis* (Bouche, 1834) (Pteromalidae Pteromalinae) is the most dominant with a proportion of 15%, followed by the species *Asaphes suspens* with a rate on the order of 10%. In the Figitidae Charipinae, *Phaenoglyphus villosa* (Hartig, 1841) represents a clear dominance in the harvested samples. In general, we found a higher abundance of Pteromalidae (58%) with a rate of 42% for Figitidae Charipinae (Fig. 4). This dominance can be explained by the adaptation to the climatic conditions of the medium by the Pteroma-

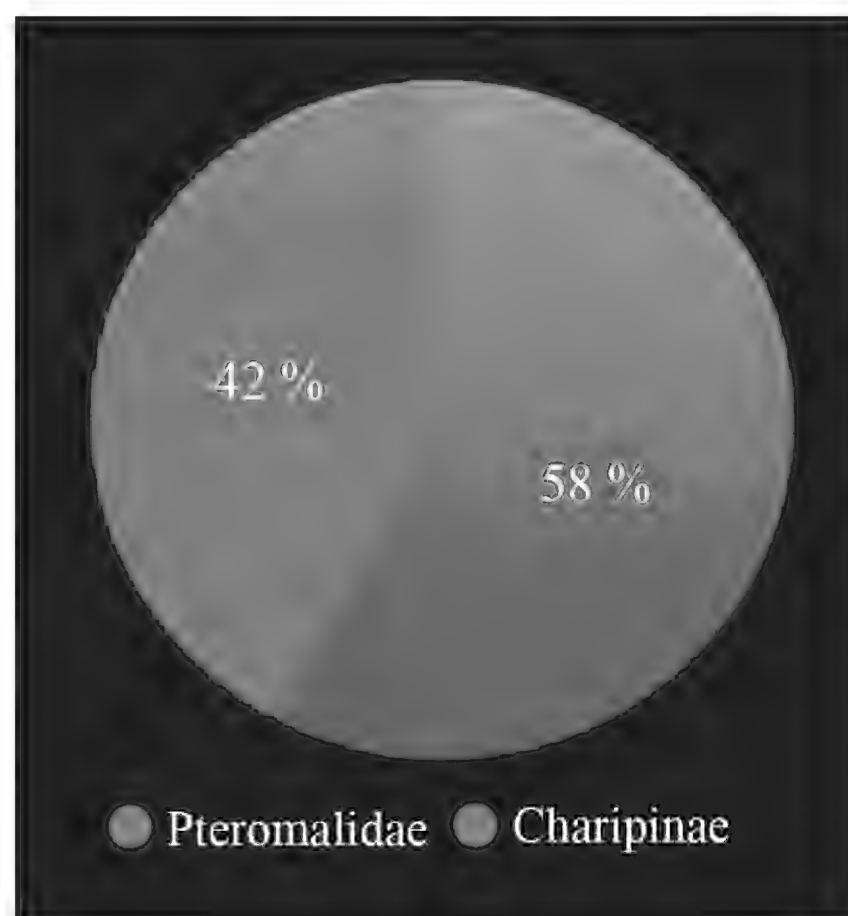


Figure 4. Average frequency of different families (sub-families) of hyperparasitoids during 2012/2014.

lidae (Hymenoptera Chalcidoidea) and Charipinae (Hymenoptera Cynipoidea Figitidae) (Fig. 4).

The results obtained during our work in the Mostaganem region on the abundance of hyperparasitoids confirm those obtained by previous works, such as Chehma (2013) in Ghardaïa (South Algeria) and Aggoun (2016), which cited several authors such as Halimi (2010) and Hemidi (2011) in Biskra (South-East Algeria) and Aggoun (2011) in Khenchela (East of Algeria), who consider that the biodiversity of hyperparasitoids studied in 2013/2014 reflects the importance of Pteromalidae in this region.

According to Sureshan & Narendran (2003), Pteromalidae is one of the most difficult group of study of the hyperparasitoids. It counts around 3400 species, distributed in 587 genera. Pteromalidae are natural enemies of several insect pests such as Coleoptera, Diptera, Lepidoptera, Hymenoptera and Hemiptera (Ghafouri-Moghaddam et al., 2014). Aggoun (2016) observed that hyperparasitoids in this family are the most active. Sureshan & Narendran (2003) were able to establish 15 tetra-trophic associations followed by species of the genus *Asaphes*. Moreover, it was found that the primary parasitoids belonging to the genera *Praon* Haliday, 1833 and *Aphidius* Nees, 1811 are the most affected by hyperparasitism. Pteromalidae play an important role in most ecosystems, mainly as secondary or tertiary consumers (Mitroiu et al., 2011).

In this study we analyze the total parasitoids obtained on several corps in the region of Mostaganem (Algeria) (Table 2).

DISCUSSION

The inventory that we carried out during the period of study allowed us to identify several species of hyperparasitoids belonging to Charipinae (Hymenoptera, Cynipoidea, Figitidae) and Pteromalidae (Hymenoptera Chalcidoidea). Among these species, we mention two species which showed a regular presence during the years of study, *Pachyneuron aphidis* of the family Pteromalidae, and *Phaenoglyphus villosa* of the subfamily Charipinae. These two species have proved to be effective in adapting very quickly to the environment.

	Pre-imaginary levels	Longevity	Complete Biological Cycle
<i>Charipinae</i>	12±4.57js (b)	6.76±0.2js (b)	18.76± 6.57js (b)
<i>Pteromalidae</i>	14±2.74js (a)	8.72 ± 4.12js (a)	22.72±6.86js (a)
Average	13±3.65js	7.74±3.06js	20.74±6.71js

Table 1. Duration of biological development of hyper-parasitoid at 25 ° C ± 02 (days).

Aphid hyperparasitoids are those attracted only by aphids that have already been parasitized by a primary parasitoid (Sullivan, 1987; Sullivan & Völkl, 1999). In the absence of primary parasitoids, some hyperparasitoids transform into primary parasitoids and even occur on non-parasitized aphids (Sullivan, 1987; Sullivan & Völkl, 1999).

High parasitism is a primary parasitoid mortality factor that reflects the nature and extent of interspecific interactions between these two groups of insects (Chehma, 2013). It has been shown that when hyperparasitoids are present, females of primary parasitoids abandon their host plots without fully exploiting the resource in order to minimize the risk of mortality of their offspring (Chehma, 2013).

Unlike parasitoids, hyperparasitoids showed a steady and significant presence during the months of May and June. This presence is related to the decrease of the parasitoids during these two months when the temperature is unfavorable for their development. On the contrary, the hyperparasitoids showed a fairly high activity during the summer period.

In parallel, other authors reported significant activity during the summer. In Algeria at Ghardaïa, Chehma (2013) reported that the action of these hyperparasitoids became very prominent during the summer period, despite the micro-climatic conditions within the oases.

In Greece, Kavallieratos et al. (2005) report that the action of these hyperparasitoids becomes very prominent during the summer period. In Canada, Acheampong et al. (2012) note that rates of hyperparasitism were much higher in the greenhouse at the end of August and early September, at 77.78 and 77.38% respectively.

Family	Sub-family	Genre	Species
PTEROMALIDAE	ASAPHINAE	<i>Asaphes</i>	<i>Asaphes suspensus</i> (Nees, 1834)
	PTEROMALINAE	<i>Pachyneuron</i>	<i>Pachyneuron aphidis</i> (Bouché, 1834)
FIGITIDAE	CHARIPINAE	<i>Phaenoglyphis</i>	<i>Phaenoglyphis villosa</i> (Hartig, 1841)
		<i>Alloxysta</i>	<i>Alloxysta arcuata</i> (Kieffer, 1902)
			<i>Alloxysta consobrina</i> (Zetterstedt, 1838) = <i>Alloxysta fuscicornis</i> (Hartig, 1841)
			<i>Alloxysta fracticornis</i> (Thomson, 1862)
			<i>Alloxysta pilipennis</i> (Hartig, 1840)
			<i>Alloxysta victrix</i> (Westwood, 1833)

Table 2. Representation of hyper-parasitism in the plan of A.F.C between 2012/2014 (annual effect).

For example, all mummies of *Uroleucon sonchi* collected in June and July gave only hyperparasitoids (Willmerand & Unwin, 1981).

It has been demonstrated that when hyperparasitoids are present, primary parasitoid females abandon the plots of their phytophagous host without fully exploiting the resource in order to minimize the risk of their offspring mortality (Ayal & Green 1993, Hölleret al., 1994, Mackauer & Völkl, 1993, Weisser et al., 1994, Buitenhuis, 2004). They affect the effectiveness of primary aphid parasitoids by decreasing their abundance and modifying their behavior (Ferrer-Suay et al., 2014).

Our knowledge of the impact of hyperparasitism on the primary parasitoid of aphids is limited and highly fragmented (Buitenhuis, 2004). Rosenheim (1998) reports that hyperparasitism severely disrupts the short-term regulation of host populations by parasitoids. However, critical studies over several generations have yet to be conducted to assess long-term effects. Moreover, a precise knowledge of the natural history of certain important groups of

hyperparasitoids is a prerequisite for improving our understanding of their origin, their distinctive biological attributes, and their role in the structure of communities (Brodeur, 2000).

This study aims a better understanding of biology and hyperparasitoid behavior as a contribution to unravel the nature of parasitoids - hyperparasitoids interactions.

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An updated checklist of the Centipedes (Myriapoda Chilopoda) of Cameroon, with new distribution records

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ABSTRACT

A checklist of Centipedes (Chilopoda) for Cameroon with updated nomenclature of old records and recent additional records from Cameroon's fauna is provided. The provisional list reveals nine endemic species (39%), four new distribution records, and includes four species that were previously omitted, thereby leading to a modest extension of the list from 19 to 23 species. Several unidentified or doubtful species no longer recognized from the African continent are excluded from the list.

KEY WORDS

Centipedes; checklist; new record; Cameroon.

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INTRODUCTION

Centipedes (Chilopoda) encompass more than 3300 species, divided into five extant orders, and are known to be from all continents, except Antarctica (Bonato et al., 2016). They are found to occur on the litter, under decaying woods, inside termite mounds as well as anthropogenic areas. Centipedes are important predators in most soil communities throughout the world. Their body is elongated, in a worm-like shape, and often flattened. The first pair of trunk appendages are developed as stinging fangs (also called forcipules), which are used to catch prey and for defence (Bonato & Minelli, 2004; Guizze et al., 2016). Centipedes mainly prey on other arthropods, but they are also able to capture earthworms and small vertebrates (Lewis, 1981; Edgecombe & Giribet, 2007; Noronha et al., 2015).

The Centipede fauna of Cameroon, one of the largest countries in central Africa, is still little-known, while the only monograph devoted to the subject (Porat, 1894) is hopelessly outdated. De-

spite being common, conspicuous, diverse, often easy-to-collect, Chilopoda have received little attention in all areas of zoological research in this country. Many available reports from Cameroon Myriapoda fauna have focused on systematic, taxonomy and ecology of millipedes. This neglect has mainly been due to the lack of experts in this new research domain in Cameroon.

The present checklist provides a review of the centipedes from old reports and recent field data with updated taxonomic names and new distribution records. This checklist is to be regarded as an invitation to further studies on the still poorly-known arthropod class Chilopoda.

MATERIAL AND METHODS

The classification for Chilopoda follows Minelli (2011). All scientific names were updated according to the recent centipede taxonomic website: <http://www.chilobase.biologia.unipd.it> (Bonato et al., 2016). Families within order, genera within

families, and species within genera are listed alphabetically. In the catalogue, the valid name of genus and species are given in bold and original descriptions are listed. Generic synonymy and/or type species provenances is listed under the valid name. In species synonymy, only references to the fauna of Cameroon were cited after original description. The cited references were followed by codification distinguishing publications with (1) taxonomic description and (2) merely listing or mention. Records from Cameroon are given with references. New records from Cameroon are given with number of specimens (male and/or female), place and georeference coordinates, date, and collector's name. The known general distribution of the species is given. Notes in terms of taxonomic status or misidentifications are given (if applicable).

RESULTS

CHECKLIST

Classis CHILOPODA Latreille, 1817
Ordo LITHOBIOMORPHA Pocock, 1910
Familia HENICOPIDAE Pocock, 1901
Genus *Lamyctes* Meinert, 1868

TYPE-SPECIES. *Lamyctes fulvicornis* Meinert, 1868 - by original designation.

SYNONYMS. *Lamyctinus* Silvestri, 1909; *Remy-lamcystes* Attems, 1951

Lamyctes (Metalamyctes) africanus (Porat, 1871)
Henicops africana Porat, 1871: 1140 (1); 1893: 5 (2); 1894: 10 (2).

RECORDS FROM CAMEROON. Bonge (Porat, 1871).

DISTRIBUTION. Cameroon, Madagascar, Senegal, Hawaiian and Juan Fernandez islands (Pocock, 1888; Attems, 1903; Zapparoli & Shelley, 2000).

Ordo SCOLOPENDROMORPHA Pocock, 1910
Familia CRYPTOPIDAE Kohlrausch, 1881
Genus *Cryptops* Leach, 1814

TYPE-SPECIES. *Scolopendra hortensis* Donovan, 1810 - by monotypy.

Cryptops (Cryptops) hortensis (Donovan, 1810)

Cryptops hortensis Donovan, 1810: 23(1); Porat, 1894: 16 (2).

RECORDS FROM CAMEROON. Bonge (Porat, 1894).

NEW RECORDS. 2 males, Campo Ma'an National Park, 2°10'N, 9°50'E, 30.IX. 2015, coll. Mbenoun & Nzoko; 1 female, same location, 2°10'N, 9°50'E, 31.VIII. 2015, coll. Mbenoun & Nzoko; 1 female, Kala Mount, 3°50'N, 11°20'E, ca 1125 m a.s.l., 29.I.2017, coll. Mbenoun & Makon (see Mbenoun et al., 2017; Mbenoun & Makon, 2019).

DISTRIBUTION. Widespread in temperate and tropical regions throughout the world, often introduced (Sseliwanoff, 1884; Porat, 1894; Attems, 1903; Verhoeff, 1943; Chamberlin, 1944; Goux, 1950; Kock, 1863).

NOTE. This species occurs mostly in temperate climate and unlikely to survive in environmental conditions different from those in its native range. Its presence in Africa required critical evaluation. Introduced specimens may occur in city gardens and similar habitats to those found in its native range.

Cryptops (Trigonocryptops) gigas Kraepelin, 1903

Cryptops (Trigonocryptops) gigas Kraepelin, 1903: 40 (1).

RECORDS FROM CAMEROON. Cameroon, without further details (Kraepelin, 1903).

DISTRIBUTION. Only known from Cameroon.

Familia SCOLOPOCRYPTOPIDAE Pocock, 1896
Genus *Scolopocryptops* Newport, 1844

TYPE-SPECIE. *Scolopocryptops melanostoma* Newport, 1845.

SYNONYMS. *Anethops* Chamberlin, 1902; *Dinocryptops* Crabill, 1953; *Otocryptops* Haase, 1887.

Scolopocryptops ferrugineus (Linnaeus, 1767)
Scolopocryptops ferrugineus Linnaeus, 1767: 1063 (1).

Otocryptops ferruginea Porat, 1893: 12 (2); 1894: 16 (2).

RECORDS FROM CAMEROON. Bonge (Porat, 1893).

NEW RECORDS. 1 male, Kala Mount, 3°50'N, 11°20'E, ca 1125 m a.s.l., 29.IX.2017, coll. Mbenoun & Makon (Mbenoun & Makon, 2019).

DISTRIBUTION. West Africa, Central America, Caribbean (Linnaeus, 1797; Gervais, 1847; Marshall, 1878; Pocock, 1888; Humbert & Saussure, 1869).

NOTE. The synonymy between *Otocryptops ferruginea* and *Scolocryptops ferrugineus* is also given by many authors, but both type materials require further revision.

Familia SCOLOPENDRIDAE Newport, 1844
Genus *Alipes* Imhoff, 1854

TYPE-SPECIES. *Alipes multicostis* Imhoff, 1854, by monotypy.

SYNONYMS. *Eucorybas* Gerstaecker, 1854.

Alipes multicostis Imhoff, 1854
Alipes multicostis Imhoff, 1854: 120 (1); Porat, 1894: 15 (2).

RECORDS FROM CAMEROON. Kitta, Bonge (Porat, 1894).

DISTRIBUTION. Cameroon, Guinea, Ivory Coast, Ghana (Porat, 1894; Imhoff, 1853; Demange, 1963).

Genus *Ethmostigmus* Pocock, 1898

TYPE SPECIES. *Scolopendra trigonopodus* Leach, 1816 - by subsequent designation.

SYNONYMS. *Dacetum*, Kock, 1847; *Heterostoma* Newport, 1844.

Ethmostigmus trigonopodus (Leach, 1817)
Ethmostigmus trigonopodus Leach, 1817: 36 (1).
Heterostoma trigonopodum Porat, 1894: 15 (2).

RECORDS FROM CAMEROON. Bibundi (Porat, 1894).

DISTRIBUTION. Cameroon, Algeria, Tanzania, Angola, Congo, Ethiopia, Malawi, Sudan, South

Africa; Tanzania (Koch, 1847; Porat, 1894; Verhoeff, 1941).

Genus *Scolopendra* Linnaeus, 1758

TYPE SPECIES. *Scolopendra morsitans* Linnaeus, 1758.

SYNONYMS. *Scolopendra (Calcaria)* Porat, 1876; *Rhombocephalus* Newport, 1844; *Trachycormocephalus* Kraepelin, 1903; *Rhadinoscytalis* Attems, 1926; *Kanparka* Waldock & Edgecombe, 2012.

Scolopendra morsitans Linnaeus, 1758
Scolopendra morsitans Linnaeus, 1758: 638 (1).
Scolopendra morsitans Porat, 1894: 11 (2).

RECORDS FROM CAMEROON. Kitta, Ekundu, Bibundi (Porat, 1894).

NEW RECORDS. 1 male, Mahonda, 4°15'N; 10°48'E, 14.XI.2013, coll. Mbenoun.

DISTRIBUTION. This well-known species is found in almost all tropical and subtropical countries (Brandt, 1841; Newport, 1844; Porat, 1894; Khanna, 1977).

NOTE. Frequently introduced.

Scolopendra valida Lucas, 1840
Scolopendra valida Lucas, 1840: 49 (1).

RECORDS FROM CAMEROON. Cameroon, without further details (Lucas, 1840).

DISTRIBUTION. Cameroon, Sudan, Somalia, Canary Islands, Iran, India, Kuwait (Lucas, 1840, Lewis, 2010; Reeves, 2016).

NOTE. This species has been previously omitted in Porat's checklist (1894).

Genus *Otostigmus* Porat, 1876

TYPE SPECIES. *Otostigmus carinatus* Porat, 1876 - by subsequent designation

SYNONYM. *Branchiotrema* Kohlrausch, 1878

Otostigmus (Otostigimus) inermipes Porat, 1893

Otostigmus inermipes Porat, 1893 :11(1); 1894 :14 (2).

RECORDS FROM CAMEROON. Bibundi, Mapanja, Bonge (Porat, 1893).

DISTRIBUTION. Only known from Cameroon.

Otostigmus (Parotostigmus) cuneiventris Porat, 1893

Otostigmus cuneiventris Porat, 1893: 10 (1) ; 1894: 14 (2).

RECORDS FROM CAMEROON. Bibundi, Mapanja, Bonge (Porat, 1893).

DISTRIBUTION. Cameroon, Tanzania (Porat, 1893; Attems, 1930).

Ordo GEOPHILOMORPHA Pocock, 1895

Familia GEOPHILIDAE Leach, 1815

Genus RIBAUTIA Brölemann, 1909

TYPE SPECIES. *Ribautia bouvieri* Brölemann, 1909 - by monotypy.

SYNONYMS. *Schizoribautia* Brölemann, 1912; *Polygonarea (Nearia)* Chamberlin, 1955.

Ribautia unguiculata (Porat, 1894)
Geophilus unguiculatus Porat, 1894: 23 (1).

RECORDS FROM CAMEROON. Patras (Porat, 1894).

DISTRIBUTION. Cameroon, Benin, Togo, Democratic Republic of Congo (Porat, 1894; Cook, 1896; Brölemann, 1926).

Genus *Schizotaenia* Cook, 1896

TYPE SPECIES. *Schizotaenia prognatha* Cook, 1896 - by subsequent designation.

Schizotaenia aequalis (Porat, 1894)
Geophilus aequalis Porat, 1894: 23 (1).

RECORDS FROM CAMEROON. Cameroon, without further details (Porat, 1894).

DISTRIBUTION. Only known from Cameroon.

Schizotaenia porosa (Porat, 1894)
Geophilus porosus Porat, 1894: 22 (1).

RECORDS FROM CAMEROON. Ekundu; Bonge (Porat, 1894).

DISTRIBUTION. Only known from Cameroon.

Schizotaenia quadrisulcata (Porat, 1894)
Geophilus quadrisulcatus Porat, 1894: 23 (1).

RECORDS FROM CAMEROON. Bonge (Porat, 1894).

DISTRIBUTION. Only known from Cameroon.

Genus *Tretechthus* Cook, 1896

TYPESPECIES. *Geophilus uliginosus* Porat, 1894 - by monotypy.

Tretechthus uliginosus (Porat, 1894)
Geophilus uliginosus Porat, 1894: 24 (1).

RECORDS FROM CAMEROON. Cameroon, without further details (Porat, 1894).

DISTRIBUTION. Only known from Cameroon.

Familia MECISTOCEPHALIDAE Bollman, 1893
Genus *Mecistocephalus* Newport, 1843

TYPE SPECIES. *Mecistocephalus punctifrons* Newport, 1843 - by subsequent designation.

SYNONYMS. *Lamnonyx* Cook, 1896; *Megethismus* Cook, 1896; *Pauroptyx* Chamberlin, 1920; *Brachyptyx* Chamberlin, 1920; *Dasyptyx* Chamberlin, 1920; *Ectoptyx* Chamberlin, 1920; *Formosocephalus* Verhoeff, 1937; *Fusichila* Chamberlin, 1953.

Mecistocephalus punctifrons Newport, 1843
Mecistocephalus punctifrons Newport, 1843: 179 (1); Porat, 1894: 20 (2).

NEW RECORDS. 1 male, Kala Mount, 3°50'N, 11°20'E, ca 1125 m a.s.l., 06.I. 2017, coll. Mbenoun & Makon; 1 female, same locality, ca 820 m a.s.l., 24.II.2017, coll. Mbenoun & Makon; 1 male, same locality, ca 1125m a.s.l., 19.IV.2017, coll. Mbenoun & Makon; 1 female, same locality, 25.XI.2016, coll. Mbenoun & Makon; 1 male, same locality, 08.IV.2017, coll. Mbenoun & Makon; 2 males, same locality, 29.IV.2017, coll. Makon; 2 females, same locality, 06.I.2017, coll. Mbenoun & Makon (see Mbenoun et al., 2017: Mbenoun & Makon, 2019).

DISTRIBUTION. India (Bonato & Minelli, 2004).

NOTES. According to Bonato & Minelli (2004), *M. punctifrons* is exclusive in India and records from Cameroon have been most probably based on misidentifications. Therefore, critical evaluation is needed. Most probably the populations inhabiting Africa are likely to be *M. togensis*.

Mecistocephalus togensis (Cook, 1896)
Lamnonyx togensis Cook, 1896: 39 (1).

RECORDS FROM CAMEROON. Ototomo (Edgecombe et al., 2010).

DISTRIBUTION. Cameroon, Togo (Cook, 1896; Edgecombe et al., 2010).

NOTES. The synonymy with *Mecistocephalus insularis*, *M. guildingii*, *M. leonensis* has been proposed by some authors.

Familia ORYIDAE Cook, 1896
Genus *Orphnaeus* Meinert, 1870

TYPE SPECIES. *Orphnaeus lividus* Meinert, 1870 - by subsequent designation.

SYNONYMS. *Andenophilus* Verhoeff, 1941; *Azygethus* Chamberlin, 1920.

Orphnaeus brasiliensis (Humbert et Saussure, 1870)
Orphnaeus lineatus Newport, 1845: 437(1); Porat, 1894: 19 (2).

RECORDS FROM CAMEROON. Cameroon, without further details (Porat, 1894).

DISTRIBUTION. Cameroon, Madagascar, Honduras, Rio Grande do Norte (Brazil), Africa (Newport, 1844; Porat, 1894; Attems, 1903; Chamberlin, 1914).

NOTE. The old record *O. lineatus* by Porat (1894) is probably *O. brasiliensis*. Therefore, critical evaluation is needed.

Orphnaeus brevilabiatus (Newport, 1845)
Geophilus brevilabiatus Newport, 1845: 436 (1).
Orphnaeus brevilabiatus Porat, 1894: 19 (2); 1893: 14 (2).

RECORDS FROM CAMEROON. Mapanja (Porat, 1894).

DISTRIBUTION. This species is widely distributed in the tropical and subtropical parts of both Eastern and Western Hemispheres.

Genus *Pentorya* Cook, 1896

TYPE SPECIES. *Pentorya afra* Cook, 1896 - by original designation

Pentorya afra Cook, 1896
Pentorya afra Cook, 1896: 34 (1).
Orphnaeus (Aspidopleres) fusatus Porat 1894: 18 (2).

RECORDS FROM CAMEROON. Ekundu (Porat, 1894).

DISTRIBUTION. Cameroon.

Familia SCHENDYLIDAE Cook, 1896
Genus *Ballophilus* Cook, 1896

TYPE SPECIES. *Ballophilus clavicornis* Cook, 1896 - by subsequent designation.

Ballophilus maculosus (Porat, 1894)
Geophilus maculosus Porat, 1894: 25 (1).

RECORDS FROM CAMEROON. Bonge (Porat, 1894).

DISTRIBUTION. Only known from Cameroon.

Genus *Ctenophilus* Cook, 1896

TYPE-SPECIES. *Ctenophilus africanus* Cook, 1896 - by subsequent designation.

SYNONYM. *Pleuroschendyla* Brölemann et Ribaut, 1911.

Ctenophilus edentulus (Porat, 1894)
Geophilus edentulus Porat, 1894: 24 (1).

RECORDS FROM CAMEROON. Bonge (Porat, 1894).

DISTRIBUTION. Cameroon.

Ordo SCUTIGEROMORPHA Pocock, 1895
Familia PSELLIODIDAE Chamberlin, 1955
Genus *Sphendononema* Verhoeff, 1904

TYPE SPECIES. *Sphendononema camerunense* Verhoeff, 1904 - by original designation.

SYNONYMS. *Pselliophora* Verhoeff, 1904; *Pseliodes* Chamberlin, 1921; *Brasilophora* Bücherl, 1939; *Lassothereua* Verhoeff, 1944.

Sphendononema rugosa (Newport, 1844)
Sphendononema rugosa Newport, 1844: 95 (1)

RECORDS FROM CAMEROON. Cameroon, without further details (Verhoeff, 1904, 1905).

DISTRIBUTION. Cameroon, Angola, Gabon, Guinea, Kenya (Verhoff, 1904, 1905).

CONCLUSIONS

The chilopod fauna of Cameroon encompasses 23 species and subspecies, nine families, and four orders including Lithobimorpha (one species), Scutigermorpha (one species), Scolopendromorpha (9 species) and Geophilomorpha (12 species) (Table 1). Nine species (39%) are so far only known from Cameroon: *Pentorya afra* Cook, 1896; *Ctenophilus edentulus* (Porat, 1894); *Tretechthus uliginosus* (Porat, 1894); *Schizotaenia quadrisulcatus* (Porat,

Order	Family	Species
LITHOBIOMORPHA	HENICOPIDAE	<i>Lamyctes (Metalamyctes) africanus</i> (Porat, 1871)
SCUTIGEROMORPHA	PSELLIODIDAE	<i>Sphendononema rugosa</i> (Newport,1844)
SCOLOPENDROMORPHA	CRYPTOPIDAE	<i>Cryptops (Cryptops) hortensis</i> (Donovan, 1810) ≠
		<i>Cryptops (Trigonocryptops) gigas</i> Kraepelin, 1903*
	SCOLOPOCRYPTOPIDAE	<i>Scolopocryptops ferrugineus</i> (Linnaeus, 1767) ≠
	SCOLOPENDRIDAE	<i>Alipes multicostis</i> Imhoff, 1854
		<i>Ethmostigmus trigonopodus</i> (Leach, 1817)
		<i>Otostigmus (Otostigmus) cuneiventris</i> Porat, 1893
		<i>Otostigmus (Parotostigmus) inermipes</i> Porat, 1893*
		<i>Scolopendra morsitans</i> Linnaeus, 1758≠
		<i>Scolopendra valida</i> Lucas, 1840
GEOPHILOMORPHA	SCHENDYLIDAE	<i>Ballophilus maculosus</i> (Porat, 1894) *
		<i>Ctenophilus edentulus</i> (Porat, 1894) *
	GEOPHILIDAE	<i>Ribautia unguicula</i> (Porat, 1894)
		<i>Schizotaenia aequalis</i> (Porat, 1894) *
		<i>Schizotaenia porosa</i> (Porat, 1894) *
		<i>Schizotaenia quadrisulcatus</i> (Porat, 1894) *
		<i>Tretechthus uliginosus</i> (Porat, 1894) *
	MECISTOCEPHALIDAE	<i>Mecistocephalus punctifrons</i> Newport, 1843≠
		<i>Mecistocephalus togensis</i> (Cook, 1896)
	ORYIDAE	<i>Orphnaeus brasilianus</i> (Humbert et Saussure, 1870)
		<i>Orphnaeus brevilabiatus</i> (Newport, 1845)
		<i>Pentorya afra</i> Cook, 1896 *

Table 1. Overview of the centipede fauna of Cameroon. Classification after Minelli et al. (2012). * indicates endemic species; ≠ indicates new records.

1894); *Schizotaenia porosa* (Porat, 1894); *Schizotaenia aequalis* (Porat, 1894); *Ballophilus maculosus* (Porat, 1894); *Otostigmus* (*Parotostigmus*) *inermipes* Porat, 1893; and *Cryptops* (*Trigonocryptops*) *gigas* Kraepelin, 1903. Six species (26%) are known from the surrounding African countries: *Ribautia unguicula* (Porat, 1894); *Otostigmus* (*Otostigmus*) *cuneiventris* Porat, 1893; *Ethmostigmus trigonepodus* (Leach, 1817); *Alipes multicostis* Imhoff, 1854; *Mecistocephalus togensis* (Cook, 1896), and *Sphenodonema rugosa* (Newport, 1844).

The overall number of centipede species (23) recorded from the historical reports and recent field data in Cameroon is greater than the number recorded to the fauna of Gabon (15 species) (Demange, 1968). Although few diversity studies have been conducted, centipedes seem to be more diverse and abundant in Cameroon (Mbenoun & Makon, 2019). Due to the lack of relevant literature and expertise of this taxonomic group, many unidentified or doubtful species have been excluded from the current list. The identification of these morphospecies may probably increase the number of centipedes present in the country. Most of data published in this catalogue were collected mainly by Porat (1894) for decades with a few under-staffed expeditions in the south-western region of Cameroon. This region is located in southern Cameroon rainforest and characterized by lowland evergreen and montane forests. A great majority of species found by Porat (1894) are likely to be endemic in Cameroon. The old data recorded from literature and those described by Porat therefore need careful revision. Accordingly, surveys should be performed in the other geographic regions within southern Cameroon rainforest so as to document their diversity and thus contribute to the knowledge of this poorly known Myriapoda class in the country.

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A phyto-climatic transect in the Alpes Maritimes used to characterize the northern limit of the Mediterranean biogeographical area

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ABSTRACT

This paper aims, with a botanical transect, to contribute to define the boundary between the Mediterranean biogeographical area and the flora of the Alpine domain. The transect, realized in 2018, is located in the Maritimes Alps, in the Roya Valley at the northernmost limit of the Mediterranean in contact with a mountain ecoregion. Our objective was to get as close as possible to the integral flora (Tracheophytes), that counts a corpus of 529 species. A 40 km long transect divided in 150 sampling sites led to 7333 observations of presence, analyzed by Factorial Composant Analysis (FCA) and frequency analysis. Statistics revealed a significant distinction of two floras with a clear spatial boundary not crossed by 76% of the species. The Transect revealed a clear biogeographic limit of biogeographical area, which seems to converge well with the limit of the Mediterranean Hotspot as defined by Myers (2000).

KEY WORDS

Phyto-climatic transect; Biogeography; Mediterranean; Hotspot; Biogeographical areas.

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INTRODUCTION

Defining biogeographical areas is a major scientific issue (Myers, 2000, Olson et al., 2001; Cox, 2001; Mackey et al., 2008; Hattab et al., 2015), especially for plants, which are less often taken into consideration when delineating these boundaries (Kier et al., 2005). However, the main challenges for biodiversity conservation caused by mass extinctions (Godet & Devictor, 2018) and the impact of climate change (Molinos et al., 2018) are a major requirement for this, whether in terms of biogeographical division of the planet (Good, 1947; Takhtajan, 1986) or because of the needs of identi-

fying particular biogeographical structures. For example, the work of Myers (1990) on defining biodiversity hotspots remains a major reference, as more recent works on hotspots overall have merely characterized or subdivided them (Médail & Quézel, 1997; Olson et al., 2001).

The definition of biogeographic areas also involves a precise, spatial examination of their boundaries (Ferro & Morrone, 2014; Morrone, 2018). An object can only be mapped accurately by validating its boundary. The boundary of a biogeographic area combines the boundaries of specific distribution areas. These rarely coincide with one another and area boundaries appear as forms of more or less

gradual transitions (Whittaker, 1967; Ferro & Morone, 2014). Making a detailed examination of the limits of specific distributions at the edges of biogeographical areas is also a particularly topical objective to understand the impact of climate change on species distribution (Molinos et al., 2018).

One of the characteristics of the Mediterranean area is that a major part of its boundary coincides with mountain ranges. These mountain ranges can be floristic provinces (Alps, Atlas Mountains) and sometimes they separate two distinct bioclimatic areas as a result of a climatic barrier effect (Cevennes, Ligurian Alps). Thus, defining the limit of the Mediterranean area requires placing the boundary between the Mediterranean mountains (high-altitude Mediterranean flora) and those at its periphery (non-Mediterranean flora). This could also appear as a matter of scale because the Mediterranean area was considered a kingdom in the same way as the Circumboreal region (Takhtajan, 1986), while the Alps a smaller subdivision only. However, a more recent work (Condé & Richard, 2002) places within Holarctic Kingdom both Mediterranean and Alps as regions of the same level. The Alps are defined as an area in classifications subdividing provinces based on an ecological approach as the Ecoregions (Olson et al., 2001). Here, we will refer to the Alpine area as being a part of the Central European region.

The Mediterranean biogeographical area has been defined and redefined over the centuries (Quézel & Médail, 2003). The inclusion of the Mediterranean area in Myers' list of hotspots and the production of a map disseminated as georeferenced and open-access files have helped to set this limit for research work and for territorial biodiversity management tools. However, this limitation of the Mediterranean hotspot and the Mediterranean biogeographical area still raises a number of questions:

- How are the species boundaries between the Mediterranean and the Alps spaced out in this area where one goes from the coastline to an altitude of 2,500 meters within a distance of just 40 kilometers?
- Does a significant limit appear? With what regeneration rate of the flora on both sides?
- Is there a transition by impoverishment or by overlap?
- Is the limit of the biodiversity hotspot the limit

of the Mediterranean biogeographical area? What is its level of spatial accuracy?

The development and increasing accessibility of large natural history or environmental databases has fostered a large majority of research programmes on biogeographical areas to develop tools for spatial analysis (classification or clustering of species, statistical characterisation of the specific patterns of pre-established regions, biodiversity hotspots or ecoregions), or the investigation of phenological variability by means of satellite imagery.

This paper relies on an original and ad-hoc field study carried out to help validate these spatial approaches to area boundaries. The naturalistic approach in the field necessarily reduces the scale of analysis when time, financial and human resources are limited, but the discussion will aim to refocus the regional terrain in a global, or at least Mediterranean, perspective, albeit, which - from a methodological standpoint - will deal with the boundaries of the areas as a whole.

Several significant regional transects have been conducted since the 1990s and 2000s to identify the Mediterranean area boundary (Alexandre, 1994; Génin, 1995; Alexandre et al., 1998a; Alexandre et al., 1998b; Godron & Andrieu, 2013). This work has made it possible to demonstrate that flora varies as a continuum without clear limits common to several species. This pattern was expected as long as it had been encountered for all other 4 transects around the northern limit of the Mediterranean area in France.

In addition to all this research, a transect was carried out in spring 2018 in the Roya valley, shedding light on the Mediterranean area boundary, which is unique because it is at one of the northernmost points of the area boundary among the Mediterranean-mountain contacts. It is one of the places where the climatic contrast is higher.

It thus contributes to define the boundary between the Mediterranean and Alpine biogeographical areas. So far, botanical investigations in the region have largely focused on overlapping floral species. For example, it is frequently pointed out that one can find Holm oaks (*Quercus ilex*) and Silver firs (*Abies alba*), which are considered to belong to very different habitats, regularly together. In addition to the continuum without clear limit, the expected pattern was a large overlap between Mediterranean and alpine Floras.

MATERIAL AND METHODS

Data collection

Gao & Kupfer (2018) demonstrated that a biogeographic regionalization must be based on spatially explicit methods and not only on ecological ones. We chose the “systematic random” transect sampling method, in which the samples are consecutive linear segments of equal size. As in every sampling, this spatial sampling should make it possible to test any hypothesis of variation modality. For effective sam-

pling, the transect must be oriented to be as heterogeneous as possible (Alexandre et al., 1998a). It was therefore to be oriented along a north-south axis where the altitudinal, and therefore climatic, gradient is the highest since it runs from the seafront to the crest line separating France and Italy (Fig. 1).

Sampling must then provide for the evaluation of the spatial variation patterns, which requires, on the one hand, a regular and continuous grid and, on the other hand, an adapted scale allowing to finely describe the variation without anthropic or edaphic microvariations prevailing over biogeographic con-

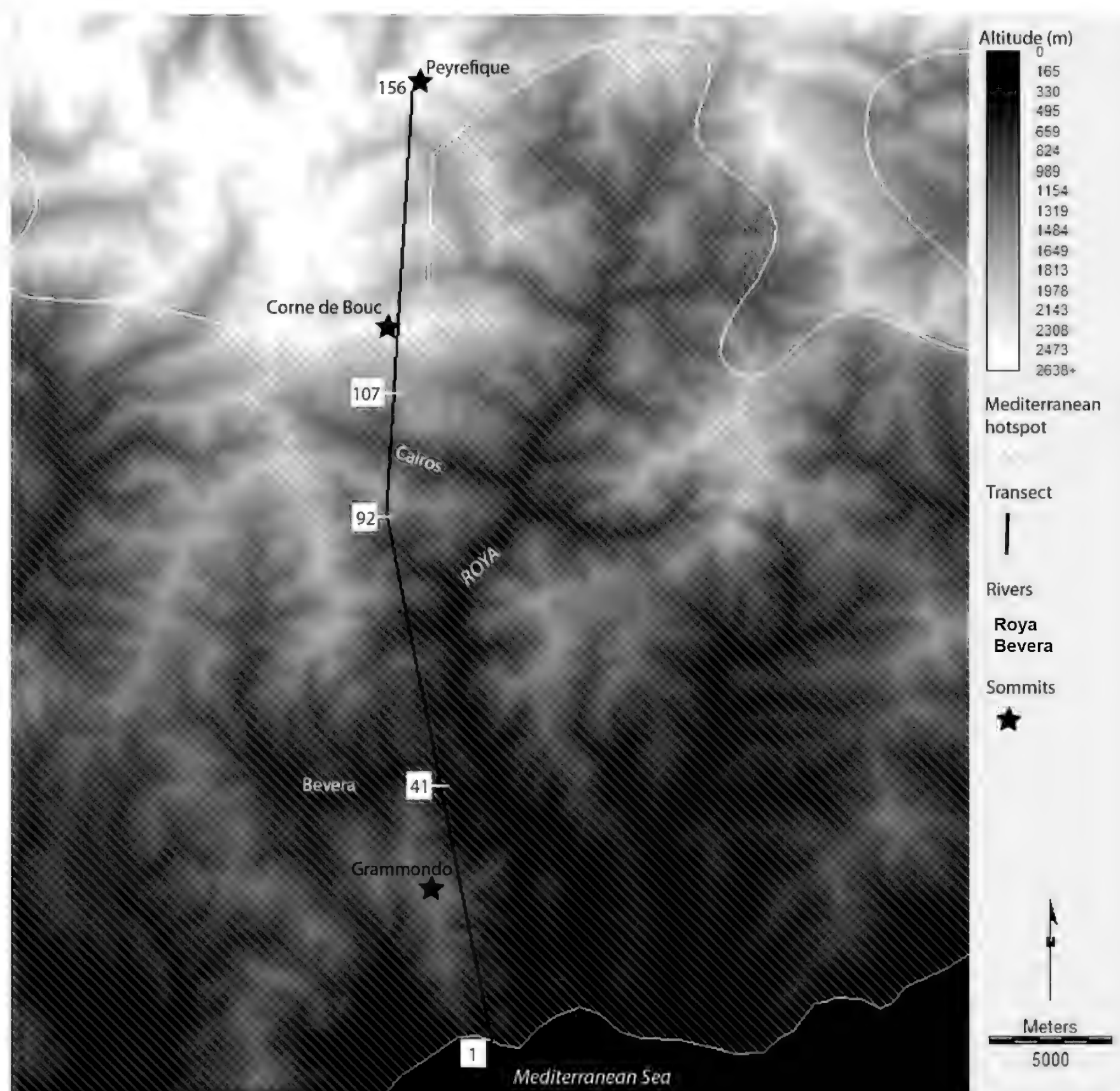


Figure 1. Map of transect location and boundary of the Mediterranean Hotspot.

siderations. Segments of 250 m by 10 m were therefore arranged in sequence along the entire transect. However, we cancelled a few segments where anthropogenic activities are too strong for proper biogeographical analysis.

Our objective was to get as close as possible to the integral flora. For this purpose, we recorded the presence of all the species identified to constitute the largest possible corpus. However, our aim was not to identify and list species exhaustively and certain taxa were excluded for some reasons like:

- Some non-flowering species could not be identified with certainty at the time of the year when the sampling took place (e.g., *Gallium*).
- Some taxon was recorded as lacking effective morphological criteria for identification (e.g., *Hieracium*).
- All green flowering monocotyledons were excluded from the study (Poaceae, Cyperaceae, Juncaceae).

Some taxa are not included due to a lack of information but the corpus of 529 species is rich enough for an original data collection. All statistics have been repeated with all species and without a set of species that might contain identification errors. Results have been very consistent, therefore, the dataset is considered as robust enough. The non-native species have been observed and included in the statistics. If native species only are usually used for biogeographic studies, we decided to describe flora as it has been observed not as it should be according to past models. The transect was carried out between April 1st and August 1st, 2018 and 150 segments of 250 meters were chained together. Only 6 samplings could not be carried out due to the overly artificial environments. Therefore, they range from 1 to 156 with missing numbers to respect the range-distance numbering. We identified 529 species and compiled 7333 observations.

Spatial analysis methods

Three indicators of floristic variation in space will be put into perspective: the coordinates of axis 1 of the Factorial Correspondence Analysis (FCA), the area/species curves and the optimal limit.

The FCA and its derivatives

The first step in the statistical analyses was a

FCA directly on the presence-absence data table. The eigenvalues of the first two axes are 12.4% and 6.6%. The factorial plane describes the main contrasts in the scatter plot. The first main component here is that which characterizes the biogeographic contrast under study.

The species-area curve

The species-area curve reflects the increase in number of species as the exploration effort progressed. It is calculated along the transect in both directions.

Structural analysis: the spatial aspect of frequency analysis

Frequency analysis highlights the significant features of frequency distributions within a set of ecological observations. It is based on the exact probability that each frequency distribution of a characteristic phenomenon will appear, such as the coexistence of two species in all the locations observed, wherever one species appears in each class of ecological descriptor such as altitude, etc. Structural analysis is a part of frequency analysis and focuses on the spatial distributions of ecological observations. The spatial distributions are here examined by the optimal limit. It is a measure of the homogeneity of the two transect sections located on either side of each of the “transitions” between two consecutive segments (between the first and second segments, between the second and third segments, etc.) and thus highlights the most remarkable transitions, which provide the most information.

To discuss the validity of the transect results beyond the simple case of a field study, we conducted a valley-wide survey with the same objective but based on the Mediterranean National Botanical Conservatory's SILENE Database using a cartographic approach. SILENE (Système d'Information et de Localisation des Espèces Natives et Envahissantes, or information and location system for native and invasive species) is a database of floristic observations made by the Mediterranean National Botanical Conservatory. Each geolocated observation of a species can be downloaded, and all the observations of a territorial entity as well, as was the case here. The surveyed territory included the French communities of the Roya Valley and those

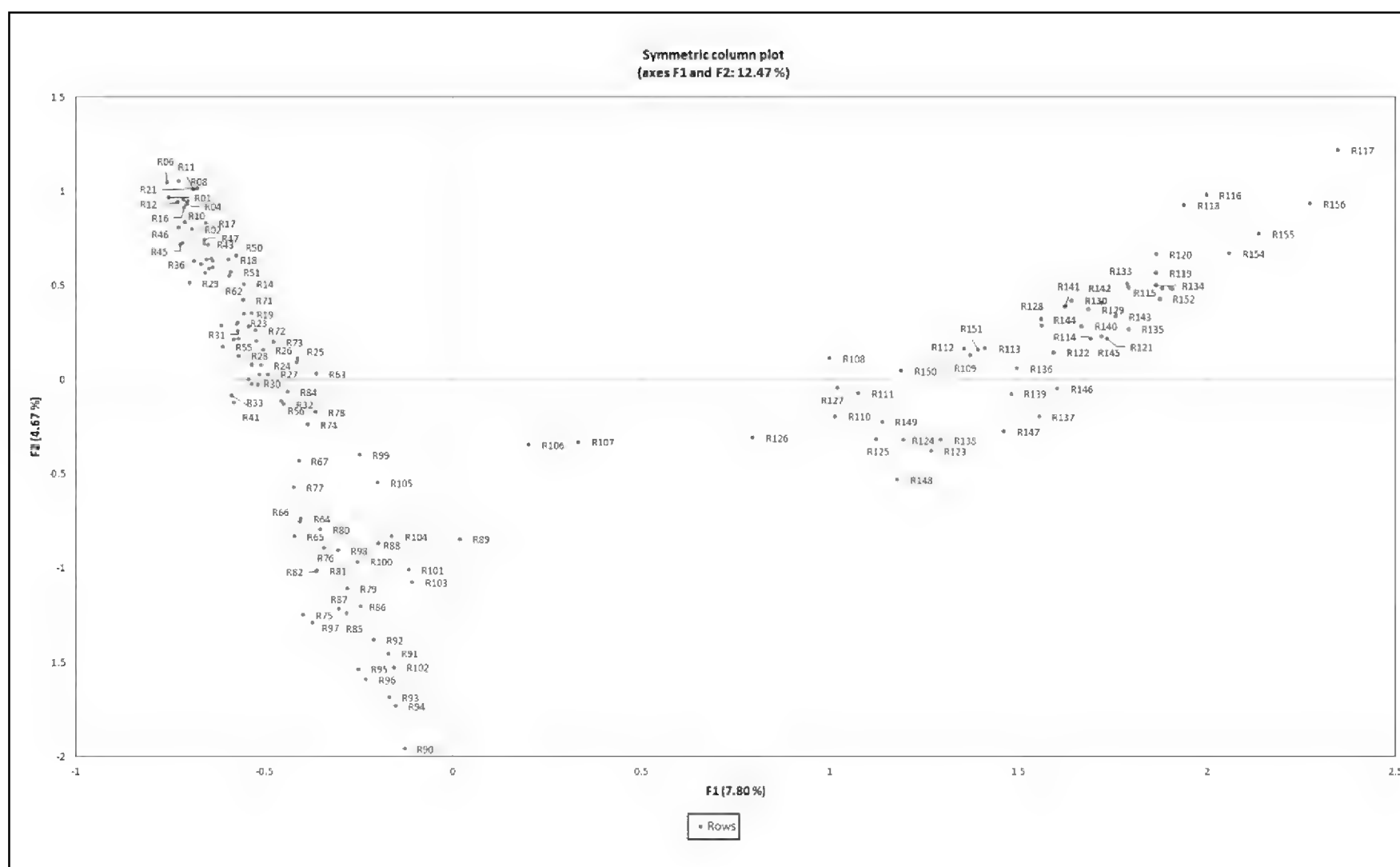


Figure 2. 1/2 factorial plane derived presence-absence data table.

bordering it west of the French-Italian border. We made 100,000 observations of 2,841 taxa (species or subspecies). First, we drew a grid of 400 m x 400 m across the whole Roya Valley and a similar area across a strip of land over French communities equivalent to the upstream Italian section to cover the same gradient to the sea. We constructed a presence-absence table based on the grid in a similar way to that of the transect. We performed a Factorial Correspondence Analysis on this data table. An unsupervised K-means classification into 2 classes was also produced. It locates the area boundary between sampling sites 107 and 108 of the transect (Fig. 5). An SQL selection allows to count the species of three distributions: present only in the Mediterranean area; present only in the Alpine area; and lastly in both areas, as defined by the K-mean classification.

RESULTS

The FCA

The 1/2 factorial plane (Fig. 2) differs from

those usually carried out on this type of data by a strong discontinuity between two groups of sampling sites, which shows that there are two distinct types of sampling sites when seen from a floristic point of view. The absence of individuals in the sampling sites at coordinates close to the origin was equally significant. A few variables (species) are visible in the centre of the 1/2 factorial plane.

Furthermore, a careful examination revealed that the two groups of sampling sites are very clearly structured spatially, since all the those to the south (from segment 1, a sampling site on the coast to number 106 by the adret slope of the Cairons valley, at 1500 meters altitude) are in the Mediterranean group on the left with negative values or close to the origin. All the sampling sites to the north (from 108 to 156, at Pointe du Sabion at 2500 meters altitude) are in the Alpine group on the right. Only sampling sites 106 and 107 appear to be a very short transition between the two biogeographic features. There is an obvious relationship between altitude and first axis coordinates (Fig. 3)

The second axis is a classification of the sampling sites of these two groups separating the open environments in positive values and the forest en-

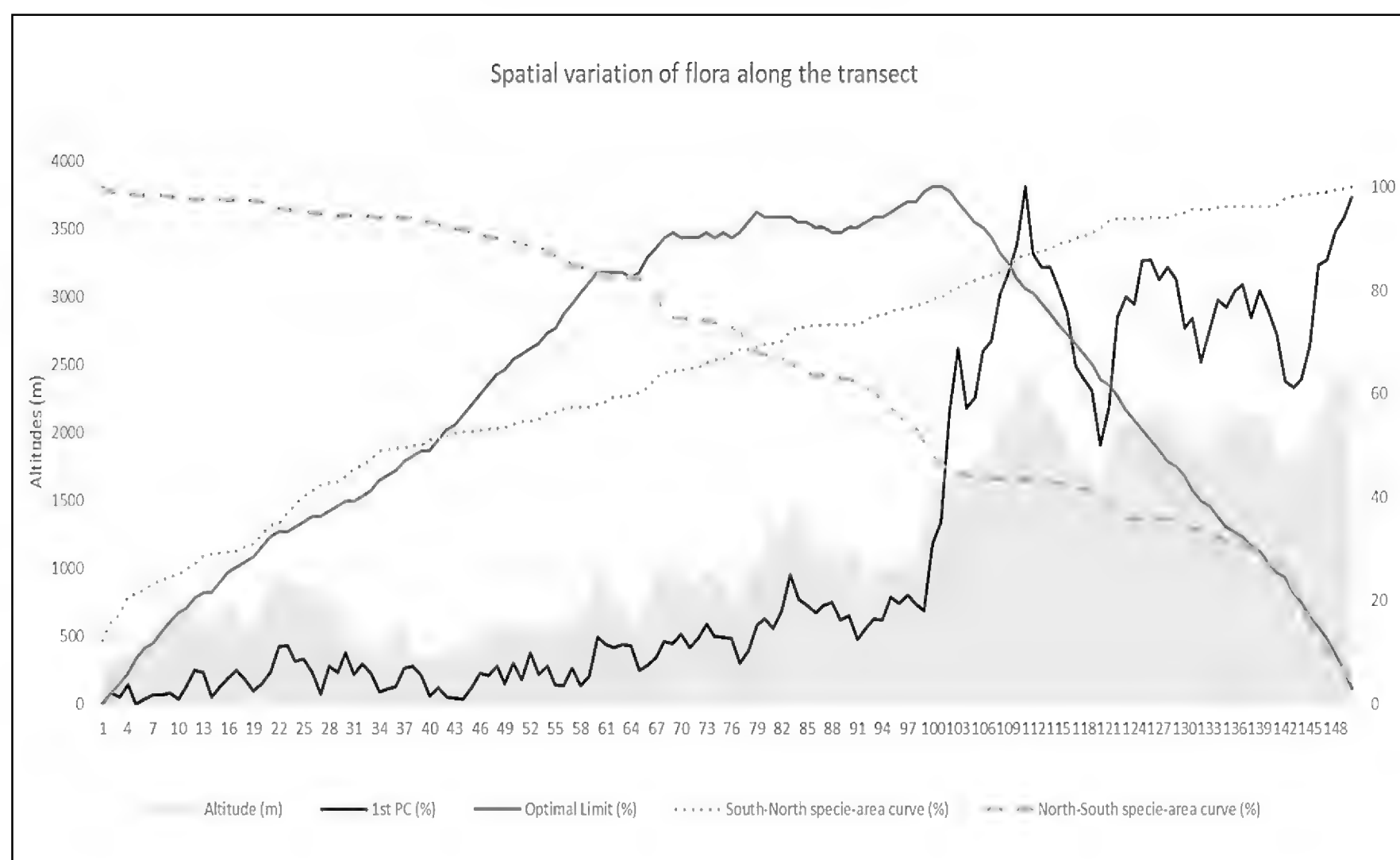


Figure 3. Spatial variation of flora along the transect.

vironments in negative values. The positive sampling sites on axis 2 and those negative on axis 1 correspond to matorrals and are associated with the most strictly heliophilic Mediterranean species (*Calendula arvensis*; *Coronilla valentina*; *Medicago polymorpha*; *Crepis vesicaria*; *Cuscuta epithymum*) or thermophile exotic species (*Opuntia ficus-indica*; *Oxalis pes-caprae*). The positive sampling sites on axis 2 and those positive on axis 1 correspond to the Alpine pastures and summits and are associated with the most strictly heliophilic Alpine species (*Saxifraga oppositifolia*, *Ranunculus pyrenaicus*, *Draba dubia*, *Adenostyles leucophylla*, *Minuartia sedoides*, *Draba aizoides*, *Petrocallis pyrenaica*, *Leontopodium nivale*).

To facilitate a graphical interpretation of these 3 indicators, all have been expressed in percentages with 0% assigned to the minimum value and 100% to the maximum value of the indicator.

Figure 3 relates these patterns to the altitude along the transect. The coordinates of axis 1, south of the transect at fairly low elevations, vary little in the form of 100-meter scale microvariations with a very slight slope of the whole between values ranging from 0 to 15% for the first 55 sampling sites and

between 10 and 25% up to sampling site No. 105. The curve then slopes extremely steeply with sampling sites 106 and 107 having intermediate values and 108 very high values. Beyond this threshold, the coordinates vary greatly according to altitude, with values between 50 and 70 % for mountain valleys and between 80 and 100 % for peaks and ridges. The first factorial axis has a correlation of 0.98 with altitude. However, it is worth noting that in the first 2/3 (Mediterranean) of the transect, axis 1 varies less than the altitude, while in the last third (Alpine), axis 1 varies more strongly than the altitude.

Species-area curves

The two species-area curves are almost linear, but there are some slight differences.

The species-area curve from north to south shows a rapidly increasing richness of Alpine species over about ten sampling sites. The trend slows down to reach a threshold around 15 sampling sites and then increases again with a few species before the threshold of the Alpine range consolidates with 40% of the flora found in the 30 northernmost

site. A major threshold is reached again, on this same slope of the Cairos valley, from sampling sites 106 and 107, where a 20% increase of the flora occurs in ten samplings. Then, a series of small thresholds show a flora enrichment until reaching a 90% flora level in 110 sampling sites where the curve gently slopes down to the coast. So there is a clear delineation of the Mediterranean flora at sampling site No. 107 on the slope of the Cairos valley as highlighted by the first 3 indicators. From south to north, the species-area curve is much less contrasted. The slope is quite steep to the south of the transect with the 50% flora level reached in 35 samplings. The slope bends somewhat gradually to reach 95% of the flora level at sampling site No. 125 before gaining the last 5% within 3 small thresholds. While the Mediterranean flora is well delimited here with very typical flora delimited by the convergence of the 3 indicators, the species-area curve from south to north shows that the Alpine flora is not a clearly defined and homogeneous flora, except by contrast to the Mediterranean flora. This may be explained by the small number of high-mountain samples and the variability of the flora between mountain forests and Alpine pastures.

The optimal limit

The optimal limit confirms and quantifies the clear separation of the two floras with a curve that increases with a few steps until it reaches its maximum value for the same transition zone between samples 106 and 107, which constitutes the optimal limit between two biogeographic entities.

Specific richness

The variation in species richness along the transect adds to this interpretation. The number of species is usually greater than 50 in the first 100 samples and then quite lower in the higher altitudes. The variation in the number of species drops rather significantly on either side of the transition between samples 107 and 108. The greatest range of low species richness samples is to be found between samples 107 and 122 (always less than 40). This confirms that the transect reflects a shift from an area with a Mediterranean endemism (and exotic species) in contact with Alpine flora and that this contact occurs by impoverishment and not by an overlap of the two flora.

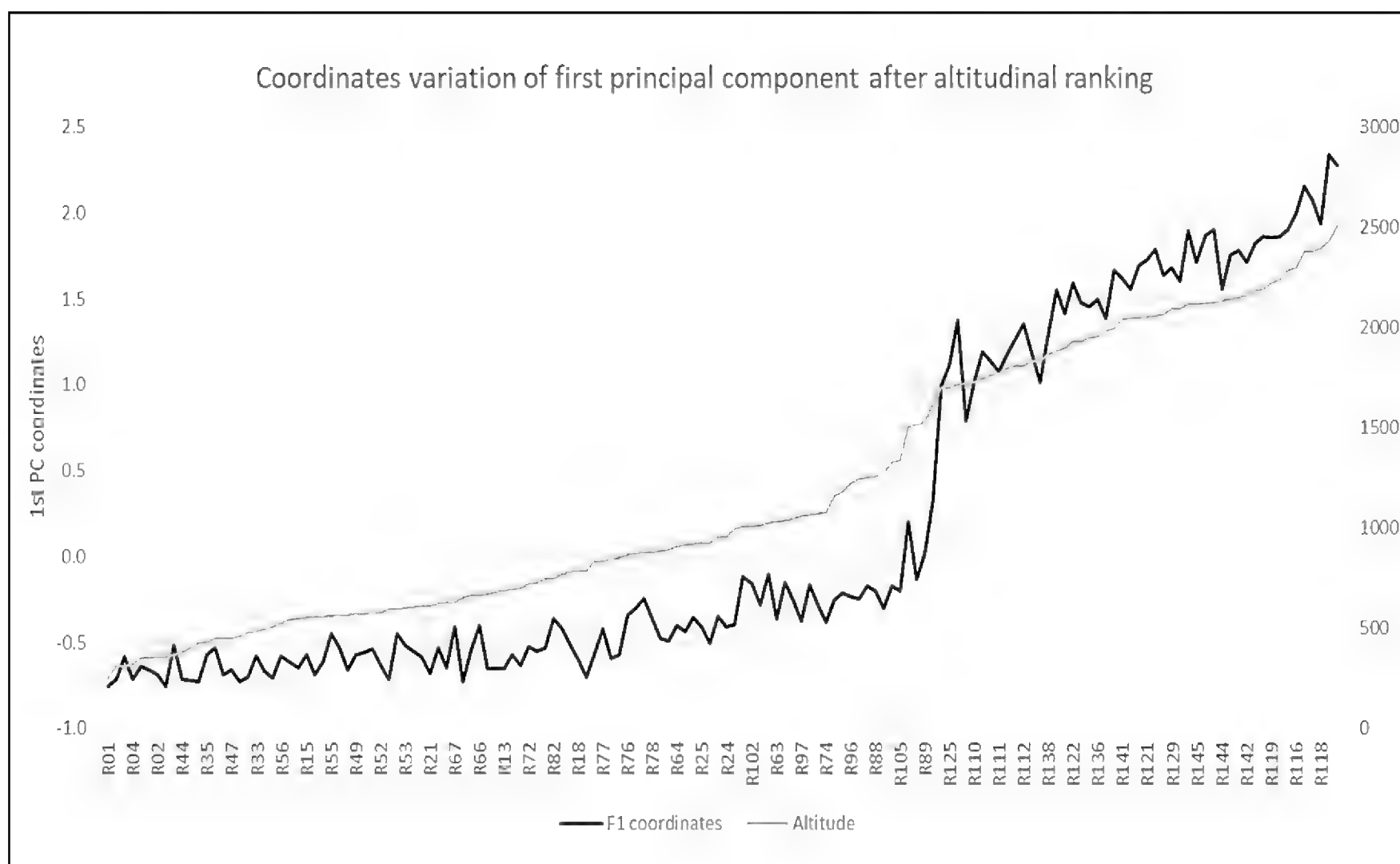


Figure 4. Altitude variation of axis 1.

The classification of the surveys by altitude rank (Fig. 4) shows that all the altitudes were sampled, even if the sampling effort, in fact, is somewhat weak around 1300 meters. At around 1650 meters, the curve takes a very steep slope to reach the higher values (Alpine flora). The break in floristic continuity, as seen from a spatial point of view (Fig. 3) between samples 106 and 107, converges with that in floristic continuity as considered from an ecological standpoint around altitudes between 1500 and 1600 meters.

The detailed examination of samples 89 and 90 is interesting. The altitudes are quite high (1510-1530 m), higher than the next 16 sampling sites and this altitude is only found on sites 105 and 106. Furthermore, samplings 89 and 90 are a summit and north-facing slope while sampling sites 105 and 106 are on the adret side. A strictly ecological interpretation would lead to expect more Alpine flora for sample sites 89 and 90 than for 105 and 106, but the type of flora is actually much more Mediterranean. This could lead us to infer that the spatial boundary (100 samples in the south and 50 in the north) is stronger than the ecological boundary on either side of an altitude or its corresponding thermal conditions.

A detailed examination of the species distributions in relation to this boundary shows that if the transect is split in two, between samplings 107 and 108, 115 species are found only im the north and 287 species only south of the boundary. Therefore, 76% of the species are related to the boundary, which is a particularly high rate (Tables 1, 2).

The validation by a close analysis, on all the SILENE points (see supplementary material) validates that the flora changes rapidly at the level of the 107 survey, generalises the limit between the two biogeographical sets at the valley scale and quantifies, on a cartographic basis, with more species, that 52.6% of the species are only restricted to the Mediterranean part, accompanied by 10.1% of species only restricted to the Alpine part.

DISCUSSION

The main result of this statistical analysis of the transect is the clear-cut boundary that separates the Mediterranean flora that appears homogenous and the Alpine flora that appears less homogenous with an altitude-dependent variation quite related to a differentiation between forest flora and grassland flora.

However, this result is only of interest in biogeography if it is valid on smaller scales. The transect was deliberately located at the contact zone between the Mediterranean area and the Alpine chain where the gradient is strongest. The transect goes from sea level to 2600 meters in 40 km. Its configuration comprise a topographic leap, since the slope of the Cairos separates the valley bottom (at 870 m) and the summit of the Corne de Bouc (at 2430 m) in only 5 km, i.e., 20 segments of the transect. One may quite reasonably assume that these topographic features induced an increased contrast

	North only	South only	Common	Total
Species richness	115	287	127	529
Percent of total	21.7	54.3	24	100.0

Table 1. Species distribution by transect range limit.

	North only	South only	Common	Total
Species richness	287	1494	1060	2841
Percent of total	10.1	52.6	37.3	100.0

Table 2. Species distribution according to area limit on the SILENE dot grid.

and that a transect a few hundred meters further east or west, where this difference in elevation would have been spread out over a greater distance, would have been less contrastive.

However, a second analysis discussed in the supplementary material section made it possible to carry out a presence-absence FCA over the whole Roya valley and not only along a sampling line. This provides an overview of the transition to high mountains in this valley. The unsupervised classification of the FCA coordinates locates the boundary in the same area as the transect and thus broadens it to the whole valley. We can see two rather compact entities, although a few islands and enclaves appear. The SQL selection for quantifying species that do not cross the line reveals lower rates than those of the transect (62.7% versus 76.4%). This proves the transect to be drawn in the most contrasted area. This was the original intention supporting this sampling choice. However, although the total volume is lower, it is still clear that the limit coincides spatially and that the rates of

Mediterranean species not crossing the line are very close, 54.3 % on the transect and 52.6 % on the grid. This limit, highlighted by the transect, should therefore be generalised, especially that of Mediterranean species, more than that of Alpine species.

The representativeness of the results is commensurate to the scale of the valley but it remains very large scale in relation to the Mediterranean biogeographical area. However, this grid analysis also made it possible to map the difference between this boundary and that of the Mediterranean hotspot. Although differences appear at this scale, as the Hotspot boundary is higher in the north-west and lower in the south-west, these boundaries are often only a few hundred meters and, at most, a few kilometers away from one another. This field campaign and the complementary analysis under a GIS validates very clearly the outline of the Mediterranean Hotspot, that can be downloaded as GIS dataset (www.cepf.net). However, we cannot broaden this spatial validation to sectors where the hotspot boundary lies in a plain. It can be assumed that the configuration described here is characteristic of the boundary of the Mediterranean area when it is in contact with the mountain flora of another biogeographical area.

CONCLUSIONS

The species boundaries between the Mediterranean and the Alps, an area where the climatic gradient is short, seem to be concentrated in a medium mountain sector at altitudes of around 1500 meters. A vast majority of Mediterranean affinity species end before this threshold and the Mediterranean region, thus delimited, is characterized by a fairly clear homogeneity. This significant limit, which appears on the transect on the adret side of Cairois river, could be generalized by a line separating the low and high areas of the study area. The renewal of the flora on either side of this line is 76% according to the transect. It amounts to 62% according to geomatics. This is a transition by depletion since less than a quarter of the species extends across this line and their limits are at varying distances from it. Samplings north of the line are characterized by relatively low richness. The breadth of the transition zone seems particularly reduced (a few hundred meters).

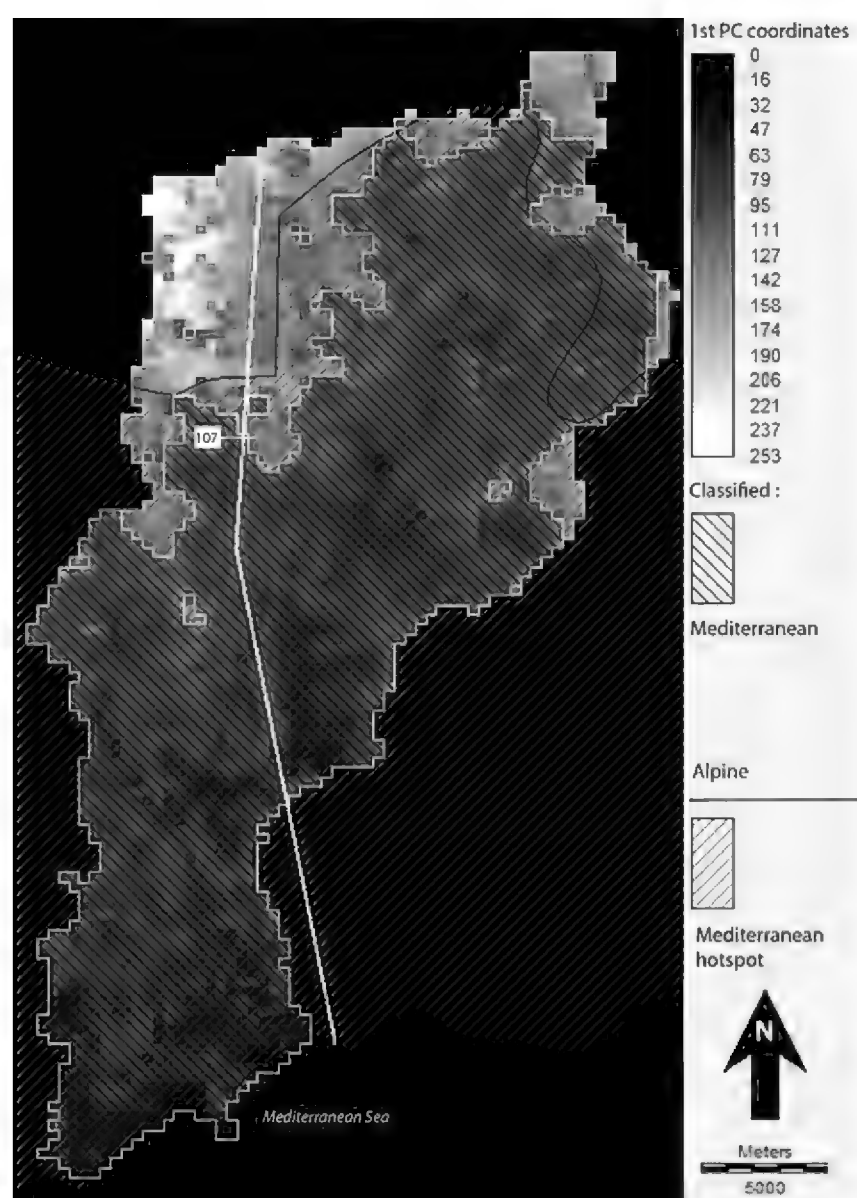


Figure 5. Classification of biogeographical areas and boundary of the Mediterranean hotspot.

The boundary of the hotspot and the boundary of the Mediterranean biogeographical area seem to converge well if one examines these lines on the macro-regional or global scale where the hotspot boundary was drawn. There are a few hundred meters of difference between the two lines, sometimes locating the hotspot, sometimes the area higher up.

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Two new *Helobdella* species (Annelida Hirudinida Glossiphoniidae) from the Intermountain region of the United States, formerly considered as *Helobdella stagnalis* Linnaeus, 1758

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ABSTRACT

Two *Helobdella stagnalis*-like leech specimens (Annelida Hirudinida Glossiphoniidae) were histologically examined from Nevada in the Great Basin, and from Utah in the Colorado River Basin (USA) to determine whether or not their crops were similar to those in *H. californica* Kutschera 1988. The Nevada form was brown and with pigmentation patterns, whereas the Utah form was plain and white. The dorsoventral histological sectioning of these 3 specimens showed the Utah and Nevada forms had compact salivary glands, hitherto noted only in the South American *Helobdella* and *Haementaria* species. The pharynx of Nevada individuals was S-shaped, and in the Utah form the ejaculatory ducts formed a Gordian knot in the distal-most posterior region, further distinguishing these 2 intermountain *Helobdella*-isolates. Comparing these two taxa to other published *Helobdella* internal morphologies, two new species are proposed: *Helobdella humboldtensis* n. sp. from Nevada (size and pigmentation similar to *H. californica*) and *Helobdella gordiana* n. sp. from Utah, which resembles *H. stagnalis* from Europe. These findings suggest the Intermountain area may be a prime region to study the evolution of members of the *Helobdella* species complex.

KEY WORDS

Hirudinida; *Helobdella stagnalis*; Leeches; Evolution; new species.

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INTRODUCTION

In this last century, the two-eyed flat leech *Helobdella stagnalis* Linnaeus, 1758 (Annelida Hirudinida Glossiphoniidae) was considered a Holarctic species with no morphological differences (Klemm, 1985; Sawyer, 1986; Siddall & Borda, 2003). Using molecular phylogeny, Siddall et al. (2005) resurrected the Nearctic (North American) taxon *H. modesta* Verrill 1872, which was distinguishable from the Palearctic *H. stagnalis*, based on one specimen from each continent.

Moser et al. (2011) re-examined *H. modesta*

(i.e., Verrill's type locality, using specimens from Connecticut) and noted a 15 % genetic divergence between Connecticut (USA) and England (UK), 16% between Connecticut and Ohio, and 18% between Ohio and England. Using 1.8% per million years (see Smith and Dowling 2008 for the intermountain fish *Rhinichthys osculus* mitochondrial DNA), these data indicate evolutionary events between the United Kingdom (Europe) and Ohio (USA) 4.4 Million years ago (Ma), and Connecticut 8.3 Ma, and between Ohio and Connecticut 8.8 Ma. These Miocene-Pliocene population antiquities suggest species stasis since this Miocene evolutionary

burst, and the Beringian trans-continental crossing from North America to Asia at this time.

The *Helobdella* Blanchard, 1896 taxonomic status has changed since the morphological species descriptions by Klemm (1985) and Sawyer (1986), and with the advent of molecular phylogenetic studies (Siddall et al., 2005; Bely & Weisblat, 2006; Moser et al., 2011, 2013; Kutschera et al., 2013). More recent efforts demonstrated even larger changes, with Beresic-Perrins et al. (2017) studying a unique site and adjacent drainages in the Colorado River Basin, and Saglam et al. (2018) describing the anatomy of 5 new species. Recently, Iwama et al. (2019) described the Sweden neo-type specimen of *H. stagnalis* and noted 6 new genetic forms over a large geographical range. As a result of these revisions, the distribution of the *Helobdella* species is unknown in the Intermountain Region of the USA (Wetzel et al., 2020).

We used the historic *Helobdella stagnalis* name in reference to all specimens lacking morphological, distributional, and taxonomic identification. Shortly after 2001, we noted populations of *H. stagnalis* with brown-colored speckles or spots, and with paramedial fine lines. To determine whether or not these specimens were members of the taxon *H. californica* (Kutschera, 1988), the first author submitted 3 specimens, the California Stow Lake Golden Gate Park *H. californica*, the Nevada pigmented *Helobdella*, and the Utah typical light plain *Helobdella*, for dorsal-ventral serial sectioning histology. The results showed the described branched caeca of the “California leech”, and its absence in the Nevada and Utah isolates, confirming the pigmented Nevada form was *H. stagnalis*.

With the recent surge of works, we resurrected the drawings made at that time and compared them to the findings of Salas-Montiel et al. (2014), Beresic-Perrins et al. (2017), and Saglam et al. (2018), noticing the Utah and Nevada anatomical features were unlike any in these illustrations. This paper first describes in more detail our reference species *H. californica*. Then, we compare the Intermountain *H. stagnalis* forms, and propose two new North American species.

MATERIAL AND METHODS

Living leeches of the genus *Helobdella* were

collected in aquatic ecosystems in Europe (Kassel, Germany) and California (USA). Populations of 5 to 20 individuals were maintained in aquaria and fed with *Tubifex* worms or *Chironomus* larvae. Photographs of these agile predators were taken as described by Kutschera & Weisblat (2015) (Fig. 1). In addition, *H. stagnalis*-like leeches were collected in the Humboldt River drainage, Nevada, and the Colorado River basin (Dolores River, Utah, USA) (Figs. 2, 3).

For microscopic observations, some of these leeches were relaxed with 10 % ethanol, fixed with 10 % formaldehyde, and preserved in 70 % ethanol while in the field (see Kutschera et al., 2013). Dorsal-ventral serial sections, (5 microns thick) of whole body mounts were prepared and stained with hematoxylin and eosin (Cathy Mayton, Wasatch Histo Consultants, Winnemucca, Nevada, USA). The drawings of the nervous, the digestive, and female and male reproductive systems (i.e., primary sex organs; gonads: ovaries and testes of these hermaphrodites) were synthesized from dissecting scope observations. Some sections were absent in the anterior region of *Helobdella californica*, due to technical problems with the block re-embedded. All observations and morphological/anatomic studies were repeated six times, using different leeches from the same population.

RESULTS

Comparison of Helobdella stagnalis and H. californica

Figure 1 shows a living specimen of a *H. stagnalis*-like leech, collected in a creek in Palo Alto, California, and a representative member of the “Golden Gate Leech”, *H. californica* Kutschera 1988. Both species are about the same size and feed on *Chironomus* larvae as well as on *Tubifex* worms. We studied the feeding behavior of these *Helobdella*-species, but were unable to detect any consistent differences. Based on these observations, we conclude that *H. stagnalis* (USA) and *H. californica* (restricted to the Golden Gate Park, see Kutschera, 2011) are closely related species, despite obvious differences in color and pigmentation.

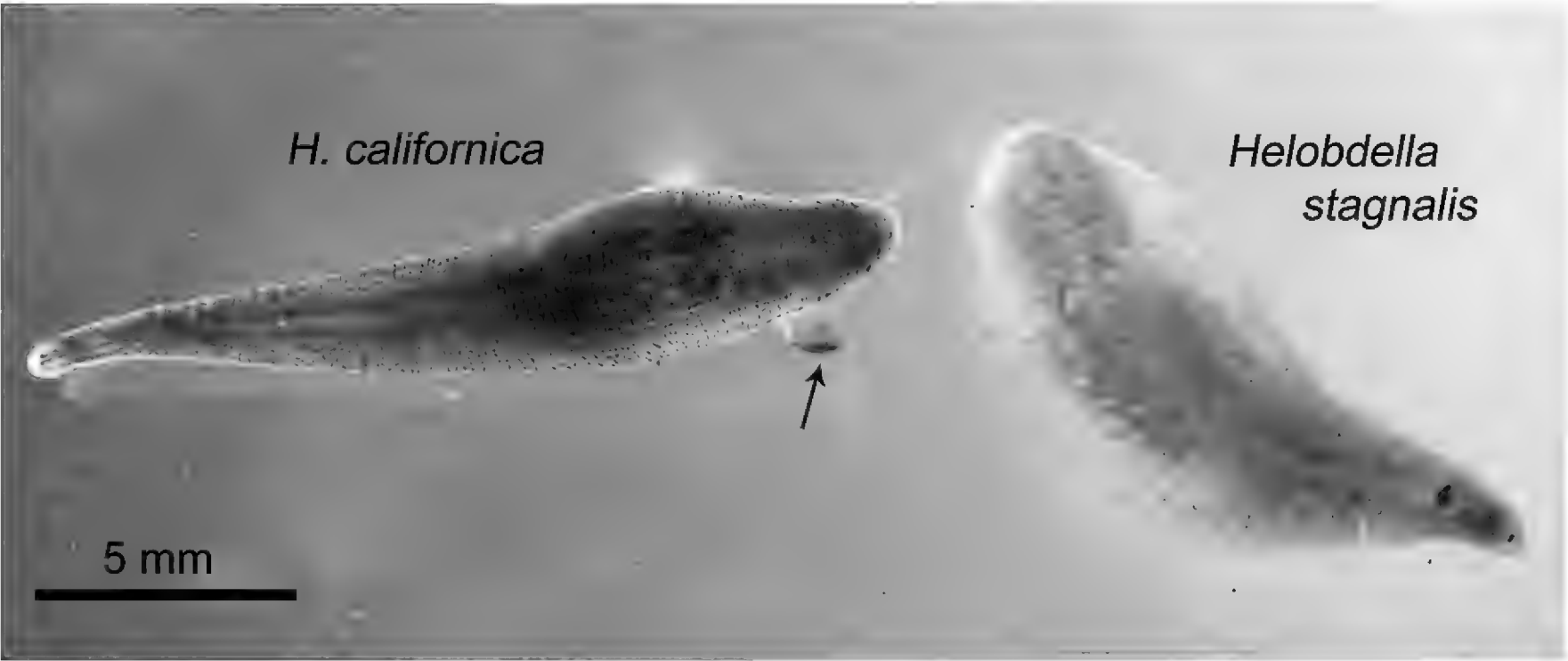
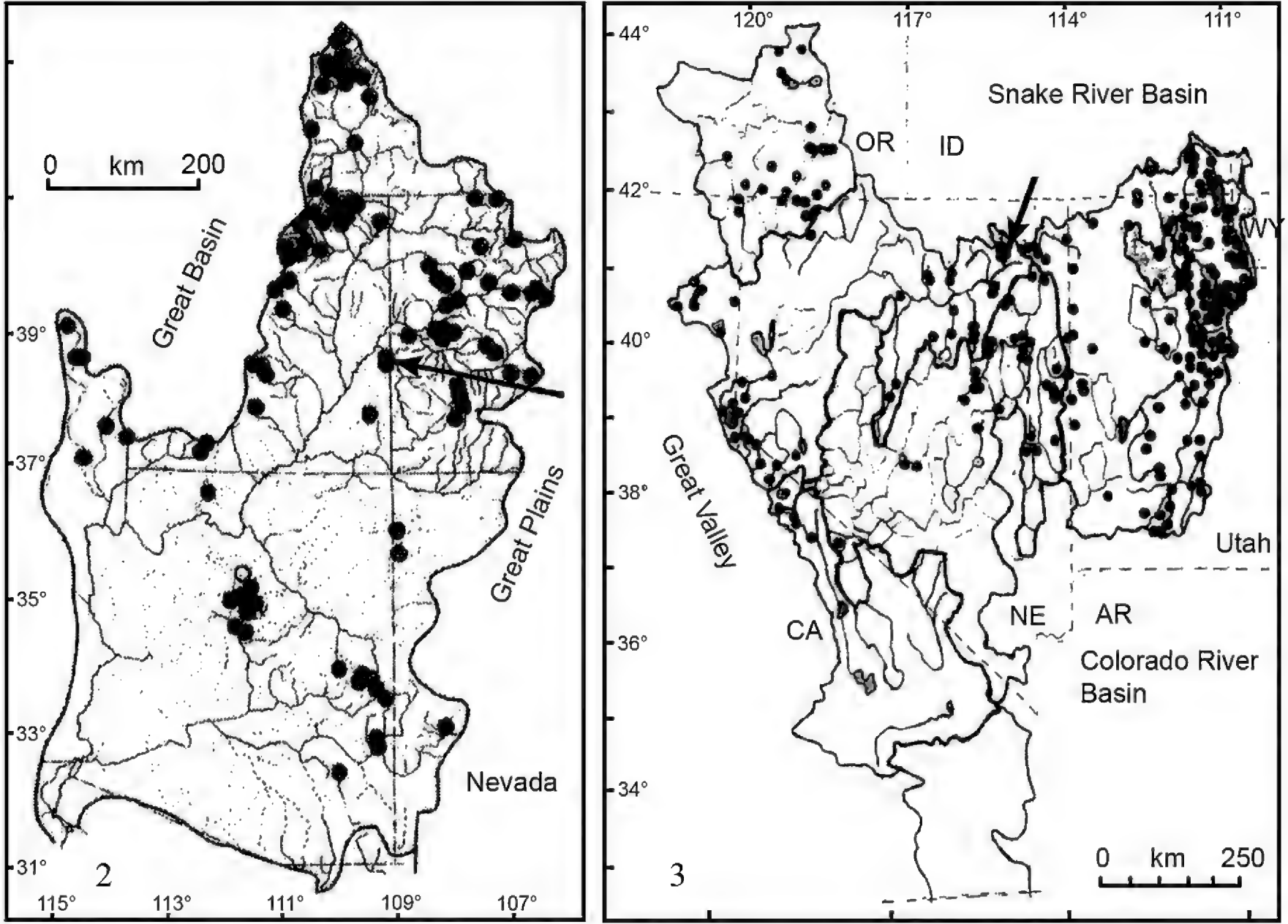


Figure 1. Photograph of living specimens of North American *Helobdella stagnalis*-like leeches. The “Golden Gate Leech” *H. californica* Kutschera 1988 is dark-pigmented; the individual carries one juvenile leech on its belly (arrow) (collected in Golden Gate Park, SF, CA, USA). The taxon on the right is, based on size and morphology, indistinguishable from its European counterpart, *H. stagnalis* L. 1758 (collected in Palo Alto, CA, USA).



Figures 2, 3. Fig. 2: the Great Basin (Nevada). Fig. 3: the Colorado River Basin (Utah). The dots show the sites where *Helobdella stagnalis*-like leeches were collected. The arrow on each map points to the 2 sites selected for *Helobdella* morphological studies.

Anatomical features of Helobdella californica Kutschera 1988

As mentioned in the Introduction, *H. californica* is considered in this context as an “outlier species” (Fig. 1).

The collected/fixed individuals of this taxon can be characterized as follows:

Site # 56. Collector # 1232. UMNH.ann. 00014 14: 4 specimens. Collected 23 Feb 2001. Pacific Coast: California: San Francisco: Golden Gate Park: Stow Lake. GEO Locate 37.769686, -122.475024. Histology serial sections: Collector # 1232. UMNH.ann.0001764. Technical problems with serial slides resulted in the absence of some anterior sections: C 02535, slides # 1–53, re-embedded # 1–25.

EXTERNAL DESCRIPTION. Color: grey, with both longitudinal and annular patterns (Fig. 1). Length: 4 specimens: 7–14 mm. Histology serial sections: length 8.7 x 2.2 mm.

DIGESTIVE SYSTEM. The pharynx transverses the atrium, descends vertically ventrally, and connects to the horizontal crop. The diffuse pair of salivary glands has bundled ductules with nearly paired origins on the pharyngeal vertical, the right ductules extending from the pharynx to the body wall for 55 microns, and the left ductules extending outward 45 microns. The crop caeca are branched (the species-identifying character), with the crop caecum # 6 not extending posteriorly. The 4 pairs of intestinal caeca angle anteriorly.

REPRODUCTIVE SYSTEM. The male linear right and left sperm duct terminates at testisac # 6 somite VIII. The posterior portions of the sperm ducts unite with the vas deferens from the 6 testisac pairs. The female left ovisac extends linear to testisac # 3 somite XVI, while the right ovisac extends linear to testisac # 5 somite XVII, both with short oviducts.

Description of the Nevada form

***Helobdella humboldtensis* n. sp.**

<http://zoobank.org/act:667AEA2C-DBD7-4704-B303-D16437775400>

Figure 4 shows the reconstruction of the internal morphology (anatomy) of *Helobdella*-isolates from Nevada. Site # 453. Collection # 914. SIUSNM #

1617002, 15 formalin fixed specimens and UMNH.ann.0001760 (Holotype, histology serial sections). Collected 11 Jun 1989. Great Basin: Lahontan Basin: Humboldt River basin: Marys River: Bathtub Spring; Nevada: Elko County: T42N, R60E, section 15d (Fig. 4): Elevation 1840 meters. GEO Locate 41.530951, -115.183065. Recollected: Site # 453. Collection # A274. UMNH.ann.0001762, 12 specimens in 95% ethanol and Collection # 3177. UMNH.ann.0001761, 4 formalin fixed specimens. 9 Apr 2020.

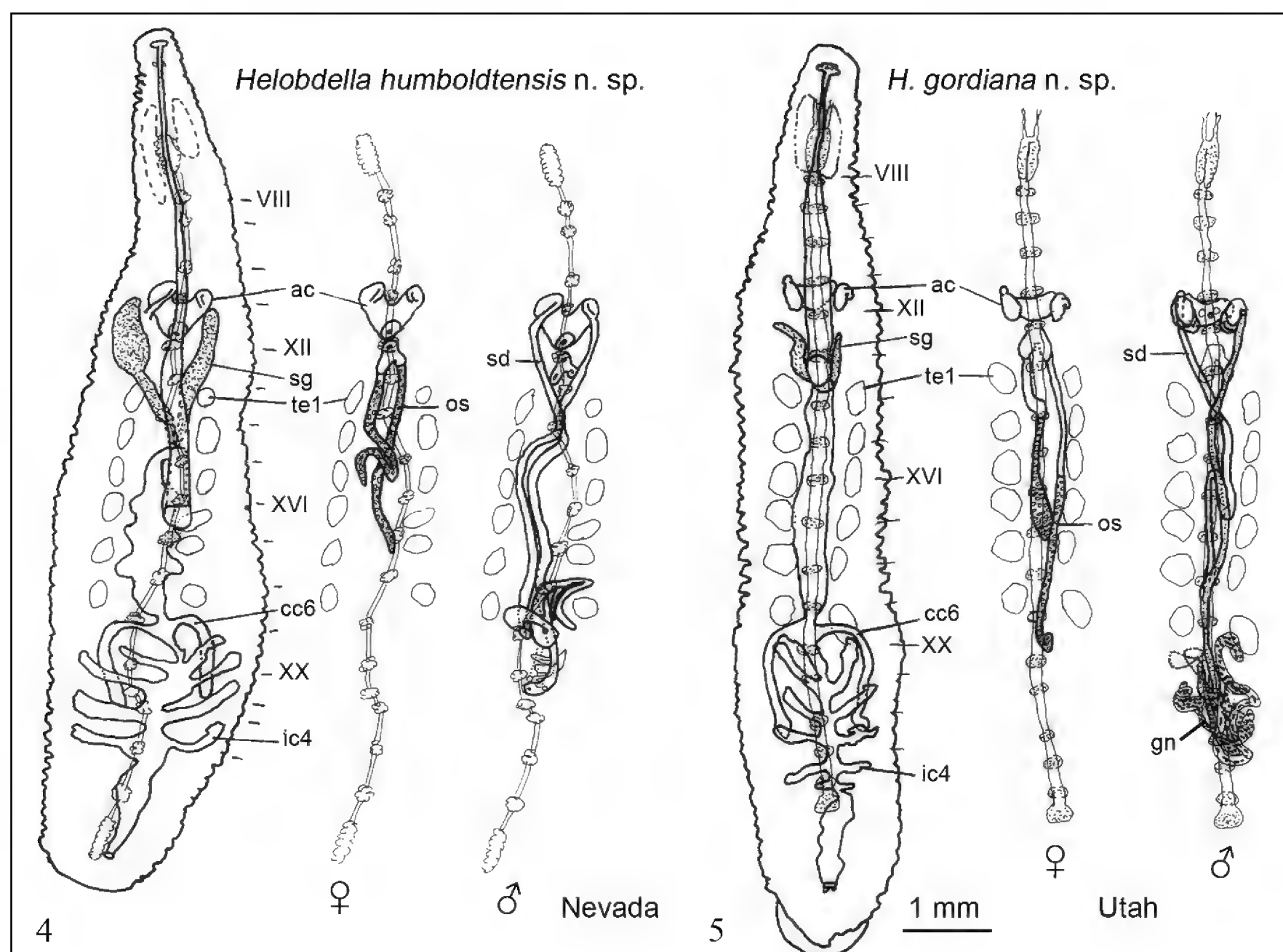
DESCRIPTION OF THE HOLOTYPE. Histology: length: 9.8 x 2.7 mm. Eyes (from histology) were separated by 1 eye width, 15 microns depth, and pigment shape as quarter moons. Digestive System (Fig. 4, dorsal view): the S-shaped pharynx, after passing posteriorly horizontally over the atrium, descend vertically (the posterior pharyngeal vertical) between testisacs #3 and #4 (Fig. 6, # 7), extends anteriorly to between testisac #2 and #3), extends vertically (the anterior pharyngeal vertical) (Fig. 6, # 6), and then leftward looping from the anterior side of the pharynx (Fig. 6, # 5), and extends posterior left of the midline as the esophagus and then dorsally vertical to adjoin the crop. This pharyngeal structure has increased total length compared to the L-shaped pharynx. The paired, compact, possessing of large cells salivary gland is directly located within the anterior pharyngeal vertical in somite XIII, beginning and ending with single cells. The right salivary gland adjoined the dorsal anterior pharyngeal vertical at the reach of the horizontal pharynx and extends dorsal anterior for 285 microns (Fig. 6, # 4). The left gland adjoins the base of the anterior pharyngeal vertical as the pharynx loops leftward and posterior, 7 microns ventral to the right salivary gland (Fig. 6, # 6), and extends dorsal anterior for 260 microns. The crop caeca were underdeveloped, perhaps because feeding had long lapsed, as suggested by Meyer and Moore (1954) for the leech *Marvinmeyeria*. The crop caecum # 6 extends posteriorly from somites XIX to XX1 (the 3rd intestinal caecum) (Fig. 4). The 4 pairs of intestinal caeca extend laterally in anterior direction. Rectum appears largely linear.

REPRODUCTIVE SYSTEM (Fig. 4). The male and female gonopores occur in somite XII, with the female ovisacs most ventral and the male sperm duct more dorsal, both ventral to the crop and intestine.

The male left and right sperm ducts extend linear, with the ducts criss-crossing the midline and each other, to a region of contortion at testisac # 5 somite XVIII, where after the left sperm duct terminates at testisac # 6, somite XIX and the right duct terminates at somite XX. The posterior portions of the sperm ducts unite with the vas deferens from the 6 testisac pairs. The female left ovisac extends posterior with double loops at testisac # 3 to somite XV, while the right ovisac extends linear to testisac # 5. Both ovisacs are of the same length, have short oviducts, and are ventral to the male sperm ducts.

VARIABILITY IN EXTERNAL APPEARANCES. The 11 June 1989, USNM 1617002 paratype and 9 April

2020, UMNH 1761, 1762 collections were examined with the UMNH specimens observed live and through the preservation process with relaxation with ethanol, fixing with 10 % formalin, and after fixing with 70 % ethanol. These processes greatly diminished the pigmentation pattern, now visible with 40x examinations. The dorsal median is plain and creme-yellowish in the anterior of compacted bodies and full length in stretched out body. The dorsal is brown with chromatophoric speckles, dense along side of the midline. During the 10 % ethanol-relaxation over a 12 hour period, the speckles disappeared, with pigment found in multiple linear longitudinal muscle lines on the dorsum and ventrum with 1 specimen having horizontal lines.



Figures 4, 5. Reconstructed leech morphology/anatomy from histological serial sections. The Nevada *Helobdella* form (Fig. 4); the Utah *Helobdella* isolate (Fig. 5). Right of the body outline: female and male reproductive organs, respectively. Atrium cornua (ac); salivary glands (sg); testisac, first of 6 pairs (te1); crop caeca, the 6th of 6 pairs (cc6); intestinal caeca, the 4th of 4 pairs (ic4); ovisac (os); ejaculatory (semen) ducts (sd). The somites are noted by right lateral lines and in part by the Roman numbers, determined by the position of the mid body ganglia. Note in figure 4 (the Nevada form) the vertical view of the lengthened pharynx, the posterior pharyngeal vertical turning anterior to the anterior pharyngeal vertical, and then, as the esophagus turning posterior, as dorsal to the crop, and the contortions of the ejaculatory duct. Note in figure 5 (the Utah form) the absence of 5 pairs of crop caeca and the Gordian Knot (gn) (i.e., ejaculatory ducts).

Length collection 15 specimens: USNM 1617002: 6–15 mm; 16 specimens: UMNH 1761, 1762: 10–15 mm. The size and pigmentation is similar to that of *H. californica* (Fig. 1). Eye separation: UMNH 1761, 1762: separated by 1 eye width (5), a half eye width (2), less than half eye width (7), and adjacent (2). The scute was most similar to figure 7 E in Saglam et al. (2018), with a circular anterior position on most of the annulus VIIa1, and a narrower posterior oval portion on the anterior annulus VIIa2.

Description of the Utah form

Helobdella gordiana n. sp.

<http://zoobank.org/act:B4CB0E45-1BF6-40C1-B819-FAC42A61DD26>

Figure 5 shows the reconstruction of the internal morphology (anatomy) of *Helobdella* isolates from Utah. Site # 107. Collection # 1195. UMNH.ann.0000584 (5 formalin-fixed specimens) and UMNH.ann.0001763 (Holotype: histology serial sections). Collected 30 Sept 2000. Colorado River Basin La Sal Mountains: Dolores River: La Sal Creek: West Fork Beaver Creek: western pond; Utah: San Juan County. T28S, R25E, section 6a (Fig. 5): Elevation 2682 meters. GEOLocate 38.404855°, -109.202434°. Re-collect: Site # 107. Collection # A276. UMNH.ann.0001767 (3 specimens, 95 % ethanol). 30 July 2020. The La Sal Mountain is an Oligocene laccolith within the Colorado Plateau Mesozoic geology.

DESCRIPTION OF THE HOLOTYPE. Histology. Length 9.8 x 2.7 mm. Eyes were separated by less than 1/4 eye width with circular partial moon eclipse appearance.

DIGESTIVE SYSTEM (Figure 5, the dorsal view). The L-shaped pharynx, after traversing the atrium, turned vertical (Fig. 7, #5) to the ventrum at testisac #1 and adjoined the horizontal crop. The paired salivary gland with compact large cells budded off the pharyngeal vertical at somite XIII. The right salivary gland (Fig. 7, #4) became emplaced within the pharyngeal vertical and extended anteriorly dorsal 120 microns. The left salivary gland (Fig. 7, # 6) became emplaced within the pharynx 14 microns below the right salivary gland, and extended dorsal and anterior for 190 microns. The salivary gland range begins and ends with single cells. The crop caeca (Fig. 5) are lacking, perhaps because of the

extended time since feeding (Meyer and Moore 1954, see above description), except for crop caecum #6 which extends posteriorly from somites XX to XXII. The intestinal caeca # 1, # 2, # 3 extend anteriorly while caecum # 4 extends laterally. There was a (parasitic?) global 60 micron thick cyst midline in the coelomic cavity posterior to intestinal # 4 caecum. Rectum appears largely linear.

REPRODUCTIVE SYSTEM (Fig. 5). The male and female gonopores occur in somite XII, with the female ovisac most ventral and the male sperm duct more dorsal, both ventral to the crop and intestine. The male ducts criss-cross the midline and each other. The left sperm duct loops at testisac #4 somite XVI, reversed directions at testisac #3 somite XV, and then proceeded posterior to the “Gordian Knot” region between somites XXI and XXIII. The right sperm duct extends linear to somite XXI Gordian knot region. The sperm ducts total length increased by 30 % with the Gordian Knot. The posterior portions of the sperm ducts unite with the vas deferens from the 6 testisac pairs. The female left ovisac extends linear to testisac #5 somite XVII, while the right ovisac extends linear beyond testisac #6 somite XX. The oviduct is 1/3 of the total length.

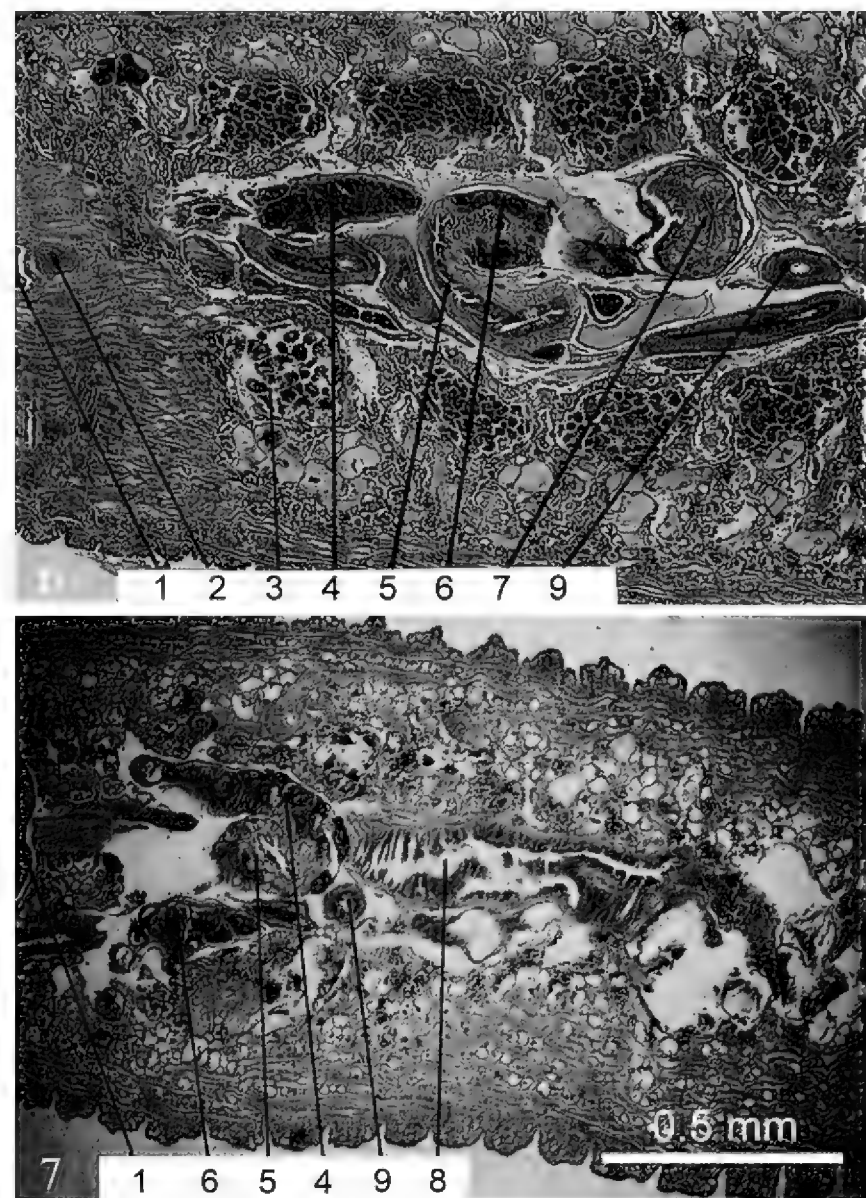
VARIABILITY IN EXTERNAL APPEARANCES. Length: UMNH 0584, 5 paratypes 5–9 mm and UMNH 1767, 3 specimens: 9–10 x 1mm. Color: white to light brown with mid dorsal clear when stretched and speckled when relaxed, changing with 70% ethanol fixation to white with speckled pattern transverse within annulus at 40 x. Eyes separation was 1/2, 1, and >1 eye width. Scute shape was D-form (see Saglam et al., 2018, Fig. 6). We examined the labial eye and scute shapes in 5 paratypes and 16 additional specimens in 5 lots UMNH 0561, 0562, 0586, 0593, 0596 from the Dolores River La Sal and Rock Creek drainages. The eyes were ovate, lateral ovate, or other, and the distance between the eyes were adjacent, 1 eye width apart, and 2 eye width apart in intrapopulations specimens. The scute shape was also irregular (Saglam et al., 2018, Fig. 6), with scute D noted but not prevalent in the 6 lots. A more extensive collection of the Utah form was collected on 5 June 2020 from Medicine Lake in upper La Sal Creek, 3093 m, GEOLocate 38.415698° -109.247677°: Site # 105. Collection # 3178. UMNH.ann.0001765. Preserved

with formalin (10), field collection # 3178 and with 95 % ethanol (29 adults, 13 juveniles) UMNH. ann.0001766, field collection #A 275. Color: live specimens appearing light and rarely dark, with dorsum heavily speckled, brownish, with irregularly wide mid dorsum light region with speckles. On 2 specimens para-medial dark lines were observed, when the specimen is stretched. The integument is sometimes transparent, with the intestinal caeca visible in 2 specimens and the eggs in the ovisac visible in 1 specimen. The fixed formalin-specimens appear very light, and with 40 x magnification reveal dorsal horizontal and ventral longitudinal rows, whereas the 95 % alcohol specimens were mostly plain and light. Length: adult 8–16 mm, juvenile 5–8 mm. The distance between the eyes varied from 1 eye width (27), half eye width (19), or adjacent width (6), and with 3 specimens having slit eyes. The scute was D-shaped (33) (see Saglam et al., 2018, Fig. 8), while the juvenile's scute was box-shaped with anterior outward curvature. Five specimens carried eggs, although additional specimens may have lost their eggs during preparation. The whitish color and 10 mm length appeared similar to that of the *H. stagnalis*-isolate from Palo Alto, CA (Fig. 1), and specimens from Europe.

Comparison with other *Helobdella stagnalis*

The morphological description of the neotype of *Helobdella stagnalis* Linnaeus, 1758 (Iwama et al. 2019) is distinct from the Nevada and Utah forms, the Intermountain types having compact salivary glands with cells embedded within the pharyngeal vertical before budding into the coelom and the right salivary gland occurring above the left. This is the first reported occurrence of compact salivary glands from a North American Helobdellid, in contrast to their presence in *Helobdella* and *Haementaria* in South America (Siddall & Borda, 2003), and in contrast to the diffuse salivary glands in the parenchyma in other North American *Helobdella stagnalis* (Saglam et al., 2018). The J-shaped pharynx of *H. stagnalis* may be distinct from the L-shaped pharynx of the Utah specimen, *H. eriensis* and *H. californica*, and from the contorted S shape seen in the Nevada specimen.

Saglam et al. (2018) were the first to illustrate different anatomies in *Helobdella stagnalis*. They described 4 Holarctic species, based on morphol-



Figures 6, 7. Serial histological section of paired salivary glands budding from the pharyngeal vertical. The Nevada *Helobdella* from (*H. humboldtensis* n. sp.) (Fig. 6); the Utah *Helobdella* type (*H. gordiana* n. sp.) (Fig. 7). The denotation Fig. 6 and Fig. 7 are placed on the anterior, left side of the leech. (1), the male gonopore (Fig. 6) or the atrial horns (Fig. 7); (2), the female gonopore; (3), the anterior #1 testisacs (Fig. 6), (4), the right salivary gland budding from the pharyngeal vertical (Fig. 7); (5), the anterior pharyngeal vertical cross-section (Fig. 7) or the ventral anterior pharyngeal vertical cross-section with the left looping to the esophagus; (6), the left salivary ducts embedded in the ventral pharyngeal vertical (Fig. 6); (7) posterior pharyngeal vertical after the dorsal horizontal pharynx from the atrial cornua turning ventral; (8), crop (Fig. 7); and (9), the ejaculatory duct fragments.

ogy, including differences in reproductive ducts, eyes, scute, gastric caeca, and rectum shapes. We have compared these species with the Utah and Nevada morphotypes, the Arizona Montezuma Well species (Beresuc-Perrins et al., 2017), and with the species from Mexico (Salas-Montiel et al., 2014), as well as the leech populations from Oregon (Moser et al. 2013). These Helobdellids all have a scute, defining the discussed *Helobdella* lineages.

The eyes and scute (6 specimens) of the Utah form and 2 lots from the Fremont River were com-

pared to the findings of Saglam et al. (2018). The intra-Utah population eyes had variable distance between them, being adjacent (1 specimen), an eye-width apart, and more than an eye width apart, even two eye-widths apart in some cases. The scute shape was also variable, the *eriensis*-shape seen in a few individuals within the 4 lots. These observations are not definitive and may result from preservation techniques in the field, and certainly the lack of studies using electron microscopy.

DIGESTIVE SYSTEM. There were 6 crop caeca, except in *H. temiscoensis* (with 5 caeca). The 6th crop caecum (the 5th crop caecum in *temiscoensis*) extends posteriorly to the 3rd and 4th intestinal caeca, except in *H. serendipitous*, *H. bowermani*, and *H. atli* extending laterally. The anterior intestinal caecum # 1 extends mostly anteriorly. The intestinal caecum # 4 extends posteriorly, except in *H. eriensis*, *H. Utah* and *H. Nevada*, where it is lateral.

MALE REPRODUCTIVE ORGANS. The male organs include the 6 pairs of testisacs (4 pair in *Helobdella octatestisaca*) connected by vas deferens ducts directed posterior between testisac # 1 and # 6, and then adjoining the posterior ejaculatory duct and then anterior to the atrial cornua and the male gonopore. The left and right male ejaculatory ducts have similar twisted lengths, extending to testisac #6 at somite XIX or beyond to somite XXIII. The left sperm duct in the Utah form is double-looped at testisac # 3 somite XV, with both sperm ducts extending posterior to between somites XX and XXIII, respectively, where they intertwine and form the Gordian knot. The Nevada form is twisted with loops at somite XXI, and not intertwined.

FEMALE REPRODUCTIVE ORGANS. The female left ovisac terminates more anterior than the right ovisac, with the Utah form extending posterior to testisac # 5 (left) and to # 6 (right), and the Nevada form to testisac #3 (right, with double loops), and to # 5, with the right and left ovisacs, having same total length. This contrasts with right and left ovisacs being of similar lengths and extending posterior to testisac # 1 (*octatestisaca*, equivalent to testisac # 3), testisac # 3 (*temiscoensis*, *blinni*), testisac # 4 (*modesta*), testisac # 5 (*stagnalis*), testisac # 6 (*atli*, *echoensis* looped), posterior beyond testisac # 6 twisted (*eriensis*). The ovisacs are linear except for the twisted (*eriensis*), curled (*echoensis*), and double-looped (Nevada). The paired oviducts

are short, with *echoensis* having a curled oviduct with a length equal to the ovisac and the Utah form oviduct reaching ~ 1/3 the length of the reference ovisac. The ovisac and oviduct length and secondary shape (curled, looped, twisted) may be useful taxonomic indicators of morphotype species, although Moser et al. (2013) noted that the ovisac length is dependent on the reproductive state of the sexually mature leech.

New Intermountain Helobdella species

We propose the Nevada and Utah forms as distinct species, based on their shared compacted salivary glands, as well as the distinct pharynx (the Nevada form) and the presence of the Gordian knot terminus of the ejaculatory duct (the Utah form).

Accordingly, we propose the Nevada form species as *Helobdella humboldtensis* n. sp. (Fig. 4) (Holotype: UMNH.ann.0001760 serial histological slides # 02549: # 1–45); paratype: USNM 1617002; type locality USNM.ann.0001761, 1762. This species is found in the Humboldt River drainage of Lahontan Basin (Great Basin). Name: based upon Alexander von Humboldt (1769–1859), honoring the initiator of many scientific disciplines, including biogeography, and the name of the river that flows past the microtome which sliced the *Helobdella* Gordian knot. The Humboldt River was first noted by European descended British-Canadian fur trader Peter Skene Ogden (1790–1854) in 1828, officially named by Fremont in 1845 with the first description of the endorheic Great Basin, and which meanders for 1600 km across northern Nevada (Houghton, 1976). Humboldt River formed from Miocene interior lakes, drained westward after breaking through the Basin and Range topography some 10 million years ago, for an unknown time entered the Pacific Ocean, and since the Pliocene has terminated within the Great Basin (Hovingh 2017). A. v. Humboldt visited the United States and President Thomas Jefferson (1743–1826) after his explorations of South America (the place of origin of the genus *Helobdella*), and left his name on towns, counties, mountain ranges, rivers, terminal saline sinks, universities, and commercial establishments of the western United States, which he never saw.

We propose the Utah form species as *H. gordiana* n. sp. (Fig. 5), based on the posterior contorted ejaculatory duct (the Gordian Knot)

(Holotype: UMNH.ann.0001763 serial histological slides # 02534: # 1–52); paratypes UMNH.ann.0000584 and UMNH.ann.0001767 found in the Colorado River drainage basin. Name: the intricate knot tied by King Gordius of Gordium in Phrygia, and cut by Alexander the Great (356–323 BC) with the prophecy that only a ruler of Asia could loosen it. In the present era, the skill of the Wasatch Histo Consultants proprietor Cathy Mayton, with her microtome, accomplished a similar feat.

DISCUSSION

Recent *H. stagnalis* phylogenetic studies have provided much confusion with regard to North American forms, largely because the serendipitously sampling of a few specimens (mostly one from one site), first as the Holarctic (European) species, and then within the Nearctic (USA). The repeated assumption of no morphological/anatomical differences within the Holarctic, and then, similarly assuming one Nearctic *H. modesta* species, has proved anomalous (Saglam et al., 2018), wrongly resulting in geographical distribution from Newfoundland (Madill & Hovingh, 2007) to the Pacific Coast (Beresic-Perrins et al., 2017). The utilization of leech morphology herein has pitfalls, namely only 3 specimens were examined and the leech population anatomical variability undetermined. Most leech anatomical illustrations show the crop caeca fully expanded, whereas we found the 3 *Helobdella* specimens with their 5 paired crop caeca essentially deflated, perhaps from the lack of feeding prior to preservation (Meyer & Moore, 1954; Kutschera et al., 2013). The internal organ shapes could be altered by the state of relaxation, the crop inflation-depression, and the sexual maturity of the leech.

The above studies have changed the views of the North American *H. stagnalis* (Fig. 1). The Great Basin surveys noted 362 *Helobdella* sites out of 2442 sites within the arid basin and range endorheic basins with thousands of springs, while the Colorado River drainage basin surveys noted 146 sites out of 937 sites within the arid drainages of the Green, the upper Colorado, the Grand Canyon, and the Lower Colorado rivers (Figs. 2, 3) (Hovingh, 2017). The Intermountain region has been noted for fauna speciation since the fish studies of Hubbs & Miller (1948), and the gastropod *Pyrgulopsis* by Hershler & Liu (2017).

The presence of two distinct species at two different sites suggests that future studies may greatly increase the number of *Helobdella* species in the western United States. The studies of Beresic-Perrins et al. (2017) also suggest such diversity within the Colorado River basin with the identification of *H. blinni*, and noting a phylogenetic species in drainages flowing northward to the Little Colorado River and southward to the Gila River. We conclude that leeches of the genus *Helobdella* may represent model organisms for the study of speciation via geographical separation. More work is required to further explore the true (hidden) biodiversity of this large group of morphologically similar freshwater leeches that evolved, millions of years ago, in South America.

ACKNOWLEDGEMENTS

The work on the biology and morphology of *H. californica* by U.K. was carried out at the Carnegie Institution for Science (Dept. of Plant Biology, Briggs-lab) in Stanford/California 94305 (USA). Support of the Alexander von Humboldt-Stiftung (AvH, Bonn, Germany, Stanford-Fellowships 2010 to 2016) is gratefully acknowledged. This paper is dedicated to the memory of Prof. Winslow R. Briggs (1928–2019), who was not only an eminent lab scientist, but also a wildlife conservationist.

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A new *Apotomopterus* Hope, 1838 species (genus *Carabus* Linnaeus, 1758) from South Guangxi province, China (Coleoptera Carabidae)

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ABSTRACT A new species of the genus *Carabus* Linnaeus, 1758 (Coleoptera Carabidae), belonging to the subgenus *Apotomopterus* Hope, 1838, from South Guangxi province, China, is described and figured.

KEY WORDS Coleoptera; Carabidae; *Carabus*; *Apotomopterus*; new species; Guangxi; China.

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INTRODUCTION

The examination of some carabid beetles (Coleoptera Carabidae) collected in southern China (Guangxi province) gave me the opportunity to identify a new species of the genus *Carabus* Linnaeus, 1758, belonging to the subgenus *Apotomopterus* Hope, 1838, closely related to *clermontianus* species group.

The new species has biogeographical significance because only very few *Apotomopterus* species inhabit that subtropical area of the Southernmost part of Guangxi Province (Deuve, 2013; Kleinfeld, 2019).

RESULTS

Systematics

Ordo COLEOPTERA Linnaeus, 1758
Subordo ADEPHAGA Schellenberg, 1806
Familia CARABIDAE Latreille, 1802
Subfamilia CARABINAE Latreille, 1802
Genus *Carabus* Linnaeus, 1758

Subgenus *Apotomopterus* Hope, 1838

***Carabus (Apotomopterus) argenticornis* n. sp.**
(Fig. 1) - <http://zoobank.org:act:D061445B-55D2-48FC-AC11-84BBBBC078CB>

EXAMINED MATERIAL. Holotype male, China, South Guangxi province, Qinzhou city, Mt. Shiwandashan, 1200 m, V.2020. The holotype is temporarily housed at the author's collection (Prepotto, Udine, Italy) waiting to be definitively deposited in a public Institution.

DESCRIPTION OF HOLOTYPE. Length including mandibles 38 mm, maximum width of elytra: 13 mm.

Upper surface uniformly black, quite mat, the primary tubercles of elytra shiny. Ventral surface, legs, palpi, antennae, and mandibles black.

Big and quite stout head; head surface very strongly punctured and very strongly wrinkled. Eyes very convex of hemispheric shape. Very long palpi, penultimate segment of the labial palpi with two or three-setae. Long antennae protruding beyond the half of the elytra; segments 5 to 11 with a dense white pubescence. Sides of the prosternal

process fully margined. Mesosternum strongly rugulose with a dense pubescence.

Big pronotum of sub-hexagonal shape, transverse (1.3 times as broad as long); maximum width at the middle, strongly sinuated before the base and regularly rounded till the apex; sides fully margined and bent upwards; hind angles large and rounded, not protruding behind its base; upper surface uniformly roughly punctured.

Elytra of oval shape, quite short; disc convex; shoulders very large and rounded; apex quite acuminate. Sculpture of elytra of triploid heterodyname type: primary intervals strongly convex forming long links interrupted by foveae, these links have a characteristic spinula at its base; secondary and tertiary intervals are smaller, forming range of grains of the same size; strongly punctured striae. Legs very long and strong.

Aedeagus (Figs. 2, 3) of subcylindrical shape, sub rectilinear in the medial part of the apical lobe; apex strongly bent, forming a tooth large and acuminate.

ETYMOLOGY. The given name wants to point out the strong white pubescence of antennae.

REMARKS. The new species is close related to *C. clermontianus* Breuning, 1933 and *C. yaophilus* Deuve, 1990 with forms a homogeneous group of species under a morphologically and biogeographically point of view (Breuning, 1933; Deuve, 1990). From *C. clermontianus*, it is easily distinguished by: larger head, surface strongly punctured, longer neck, larger and more convex eyes; segments 5 to 11 of antennae with a longer but less dense pubescence; mesosternum strongly rugulose with a dense pubescence; sides of prosternal process fully margined; bigger pronotum of sub-hexagonal shape, anteriorly rounded, hind angles larger and rounded; shorter and convex elytra; sculpture of elytra of heterodyname type; apex of male aedeagus shorter and acuminate. From *C. yaophilus*, it is distinguished by: stouter head, surface strongly punctured; stronger antennae, segments 5 to 11 with longer and less dense pubescence; mesosternum less rugulose; sides of prosternal process fully margined; more transverse pronotum; hind angles larger and rounded; larger and shorter elytra; disc of elytra convex; different sculpture of elytra: secondary intervals forming a range of grains (uninterrupted costae in



Figures 1–3. *Carabus (Apotomopterus) argenticornis* n. sp. Holotype. Fig. 1: habitus; Fig. 2: aedeagus in lateral view. Fig. 3: aedeagus in dorsal view.

yaophilus); apex of male aedeagus strongly acuminate and strongly curved.

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Shell shape variation in populations of common cockle *Anadara oceanica* (Lesson, 1831) (Bivalvia Arcidae) from the intertidal areas of Margosatubig, Zamboanga del Sur (Philippines)

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ABSTRACT

The advent of geometric morphometrics opened an area to study morphological variations in organisms. Thus, the aim of this study is to use outline-based geometric morphometrics to describe variations in the shell shapes of the left and right valves of *Anadara oceanica* (Lesson, 1831) (Bivalvia Arcidae) populations from the two neighbouring intertidal zones of Margosatubig, Zamboanga del Sur, Philippines. Herein, there were two levels of analyses that were employed: first, the shell shapes of the outer left and right valves between populations were compared; second, the shell shapes within population were quantitatively determined in terms of its symmetry. Results revealed significant variations both in the left and right valves of *A. oceanica* between populations. The variations observed are characterized by the deformations in the umbonal and anteroventral angles and in the dorsal, anterior and ventral margins of the outer shell both in the left and right valves. Although further studies are necessary in order to elucidate these variations, the second analysis revealed that the detected asymmetry in the shell shapes within *A. oceanica* populations was the cause of variation within populations that contributed to the significant variations between populations. Considering that the two sites are not geographically isolated, the results herein clearly proved that shell shape variation could also occur in neighbouring populations. The variations in the shell shapes of *A. oceanica* populations may have implications to habitat adaptation which aid in understanding the nature of this species especially those dwelling in the intertidal areas of Margosatubig, Zamboanga del Sur, Philippines.

KEY WORDS

Asymmetry; environmental conditions; geometric morphometrics, habitat adaptation; neighbouring populations.

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INTRODUCTION

The common cockle, *Anadara oceanica* (Lesson, 1831), = *maculosa* (Reeve, 1844), (Bivalvia Arcidae) is characterized by its trapezoidal ribbed

shells with a heavy periostracum and taxodont hinge. It is commonly called as cockle as it morphologically resembles the European cockle *Cerastoderma edule* (Linnaeus, 1758) (Bivalvia Cardiidae) which in fact belongs to the family Cardiidae. Thus,

this terminology does not have any taxonomic significance. Further, it is also called blood clam because of its specialised invariable occurrence of red blood pigments haemoglobin (Davenport & Wong, 1986). It typically occurs in habitats ranging from the intertidal zone on wave exposed sandy shores to the marginally subtidal areas of sheltered mudflats up to the higher tidal levels within the mangrove areas and even extend into deeper subtidal areas (Brotohadikusumo, 1994). Due to the absence of well-developed siphons, *A. oceanica* is considered as a poor burrower, meaning it cannot delve in the substrate at any depths (Brotohadikusumo, 1994). This poor burrowing behaviour of *A. oceanica* makes it highly exposed in receiving high concentrations of natural and anthropogenic wastes in the intertidal zones such as inorganic and organic nutrients, soil and sediments, and pollutants (Sithik et al., 2009). Just like other bivalves, *A. oceanica* has limited mobility that restricts its ability to avoid adverse conditions due to its sedentary behaviour (Sharma et al., 2016). Hence, populations of this species are good candidates for the detection of different types and levels of stress.

Due to the fact that shell is the most variable part of a bivalve species and is largely affected by environmental conditions (Uba et al., 2019), it has been the most widely used part in studying *Anadara* species, specifically by focusing on shell shape variation. Succeeding studies in *Anadara* species supported significant shell shape variation within and between populations (Mzighani, 2005; Faulkner, 2010; Lodola et al., 2011; Finogenova et al., 2013; Souji & Radhakrishnan, 2015; Aydin et al., 2014; Qonita et al., 2015; Meshram & Mohite, 2016). These studies, among others, focused on traditional approaches in morphometric studies (i.e., analysis of linear distances). However, these methods have some statistical disadvantages such as the difficulty in acquiring size-free shape variables from individuals as these measurements are highly correlated with size (Morais et al., 2014). With this, it is pertinent to search an applicable tool that can reliably analyze shape variability and the advent of geometric morphometrics (i.e., outline-based analysis) has come as its solution. This quantitative tool is used to determine and compare morphological shape variations of biological structures (Sansom, 2009). Thus, this method was employed in this study and is particularly advantageous compared to

the traditional method because it effectively avoids confusion between size and shape by preserving the shape variables and the main geometric properties of the samples (Webster & Sheets, 2010).

It is hypothesized that shell shape variation is an adaptive strategy of bivalves in response to its current ecological conditions (Alibon et al., 2018). Thereby, shell shape variations in *A. oceanica* populations may have implications to habitat adaptation which can help in understanding the nature of this species especially those dwelling in the intertidal zones of Margosatubig, Zamboanga del Sur, Philippines. Accordingly, pollution of marine water caused by improper disposal of residential wastes and rural run-offs is one of the main ecological concerns in this locality and that the presence of *A. oceanica* in this area suggests a tolerance to the current ecological conditions that could be influencing its shell shape. Thus, this study was conceptualized with the aim to describe variations in the shell shapes of *A. oceanica* into two levels of analyses. First, the shell shapes of the outer left and right valves between the two different *A. oceanica* populations from Margosatubig were compared using outline-based geometric morphometrics. Second, the shell shape of *A. oceanica* within population was scored for differences in shapes between its left and right valves, otherwise known as fluctuating asymmetry which is a potential bioindicator of environmental stress in populations (Trono et al., 2015).

MATERIAL AND METHODS

Description of sampling sites and collection of samples

A total of 60 adult *A. oceanica* individuals with a similar size range of 40–50 millimeter shell length were handpicked purposively from each of the two neighbouring intertidal areas in the municipality of Margosatubig, province of Zamboanga del Sur, in the Philippines; Tulog-bato, Barangay Tiguian (7°34'N, 123°10'E) and Samboang, Barangay Poblacion (7°35'N, 123°10'E) shown in figure 1. Margosatubig is bounded on the north by the Municipality of Lapuyan, on the east by the Municipality of Dimataling, on the west by the Municipality of Malangas and on the south by the Municipality of Vincenzo Sagun.

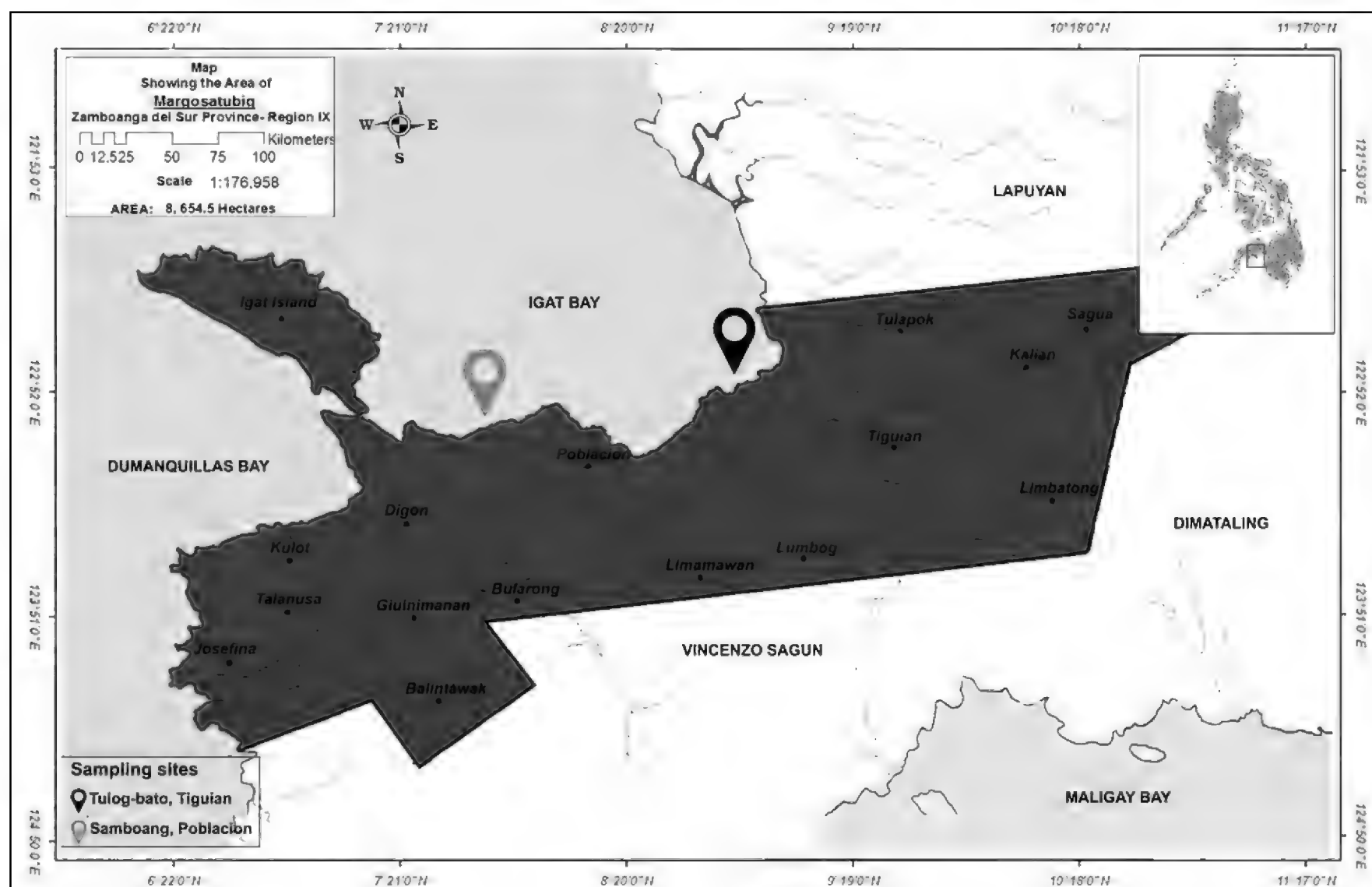


Figure 1. Map of Margosatubig, Zamboanga del Sur (Philippines) showing the location of the two sampling sites.

Margosatubig is one of the coastal municipalities of Dumanquillas Bay and Igat Bay in the province of Zamboanga del Sur which in a way it embodies dynamic ecosystems such as a mangrove estuarine ecosystem (Tulog-bato, Barangay Tiguian) and a residential intertidal area (Samboang, Barangay Poblacion). The coastline in Tulog-bato is characterized by mudflats and muddy shores with thick patches of mangroves that are partially enclosed with coastal body of water formed where freshwater from the upper land meets with saltwater, a characteristic of a mangrove estuarine ecosystem. Contrarily, the coastline in Samboang is characterized by tidal flats and sandy shores and is dominated with residential houses where gravels, coarse and sandy sediments are readily observed from the shore to the intertidal zones that are exposed to air at low tide and covered with seawater when the tide is high. It is prominent that rapidly moving water tends to carry larger and heavier sediment particles washing away smaller particles and preventing their deposition. Hence, tidal flats with low energy water movement are characterized by more muddy sediments such as that of in Tulog-

bato whereas in higher energy regimes with stronger currents and moderate wave action, the flats are generally composed of courser sandy/muddy sediments similar to that in Samboang. The taxonomy follows WoRMS (2020).

Preparation and imaging of samples

The samples were cleaned off from their soft tissues before the shells were sun-dried. The umbonal angle is distinguished clearly in the outer valve (Fig. 2). The left and right valves are identified in the inner valve based on the position of its pallial sinus wherein the left valve's pallial sinus curves to the left and the right valve's pallial sinus curves to the right (Fig. 3). The outer left and right valves of *A. oceanica* were oriented in the same position, respectively. Then, samples were photographed using Nikon D7000 with a pixel size of 4.78 μm ensuring that the samples and the lens of the camera were at uniform focusing distance of 0.8m. Images of the samples were triplicated in order to minimize source of error and bias and then numbered respectively to identify the sequence of the samples.

Outline-based data acquisition and statistical analyses

A total of 100 points were established for the outline curve of the outer left valve (Fig. 4) and right valve (Fig. 5) contour in *I* using tpsDig version 1.36. After processing of outline curve, the thin plate splines (TPS) curve was converted into landmark points or XY coordinates using tpsUtil version 1.36 to build TPS file and make link files (Rohlf, 2004). The raw landmark coordinates are first superimposed using Generalized Procrustes Super Position Algorithm, whereby the sum of squared distances between each object and a reference configuration (consensus) are iteratively minimized by translations and rigid rotation (Khiaban et al., 2010). The partial warp (Generalized Procrustes Super Position Algorithm) scores of these superimposed data are used as shape variables (Sepe et al., 2019). The TPS interpolation function derived from the mean of the superimposed data is applied to a squared grid overlaying the mean landmark configuration to provide a direct and quantitative implementation. The consensus shape data of each separate groups are measured by relative warps ordinations plots using tpsRelw version 1.36. The RW scores are computed from the partial warps (Rohlf, 2004).

To statistically test the hypothesis that the shell shapes of *A. oceanica* populations vary between the two sites, Multivariate Analysis of Variance (MANOVA) was used based on the generated RW scores for the shape of *A. oceanica* populations using Paleontological Statistics (PAST) version 3.0 Software, results with $p < 0.05$ are considered statistically significant. MANOVA is a form of multivariate measure which tests whether several samples have the same mean shape (Sepe & Demayo, 2014; Madjos & Anies, 2016). Canonical Variate Analysis (CVA) was done using the same version of the software mentioned above to determine variations among groups relative to the pooled within group variation generated from the RW scores and the canonical variates displayed as an ordination and were scattered within groups (Hammer et al., 2001; Madjos et al., 2015).

Measurement of asymmetry levels

The analysis of asymmetry in the shell shapes of *A. oceanica* was based on matching symmetry

considering that the left and right valves are pairs of separated structures (Savriama & Klingenberg, 2011). Consequently, the reflection was removed by transforming all configurations from one body side to their mirror images (Klingenberg et al., 2002). After the conversion of the outline TPS curve into landmark points or XY coordinates using tpsUtil version 1.36 (Rohlf, 2004), Symmetry and Asymmetry in Geometric Data (SAGE) Program version 1.04 was then used to evaluate the fluctuating asymmetry (FA) levels of the x and y coordinates of the landmarks per individual using a configuration protocol (Marquez, 2014). Procrustes superimposition analysis was performed with the original and mirrored configurations of the shells, simultaneously.

A Two-Way, Mixed-Model Analysis of Variance (ANOVA) was used to test the significance of the following effects: Individuals, Sides, Individuals x Sides. The effect called Individuals refers to the variation among individual genotypes while the Individuals mean square is a measure of total phenotypic variation. The effect called Sides refers to the variation between the two sides and it is a measure of directional asymmetry. The Individuals x Sides interaction is the failure of the effect of individuals to be the same from side to side otherwise known as fluctuating asymmetry. The error term is also included as effect which is the Measurement Error and it is a random effect (Graham et al., 2010; Alibon et al., 2019). In addition, Principal Component Analysis (PCA) was performed in the same software to detect the components of variances and deviations for the samples to carry out an interpolation based on a TPS and then visualize shape changes as landmark displacement in the deformation grid (Marquez, 2014).

RESULTS AND DISCUSSION

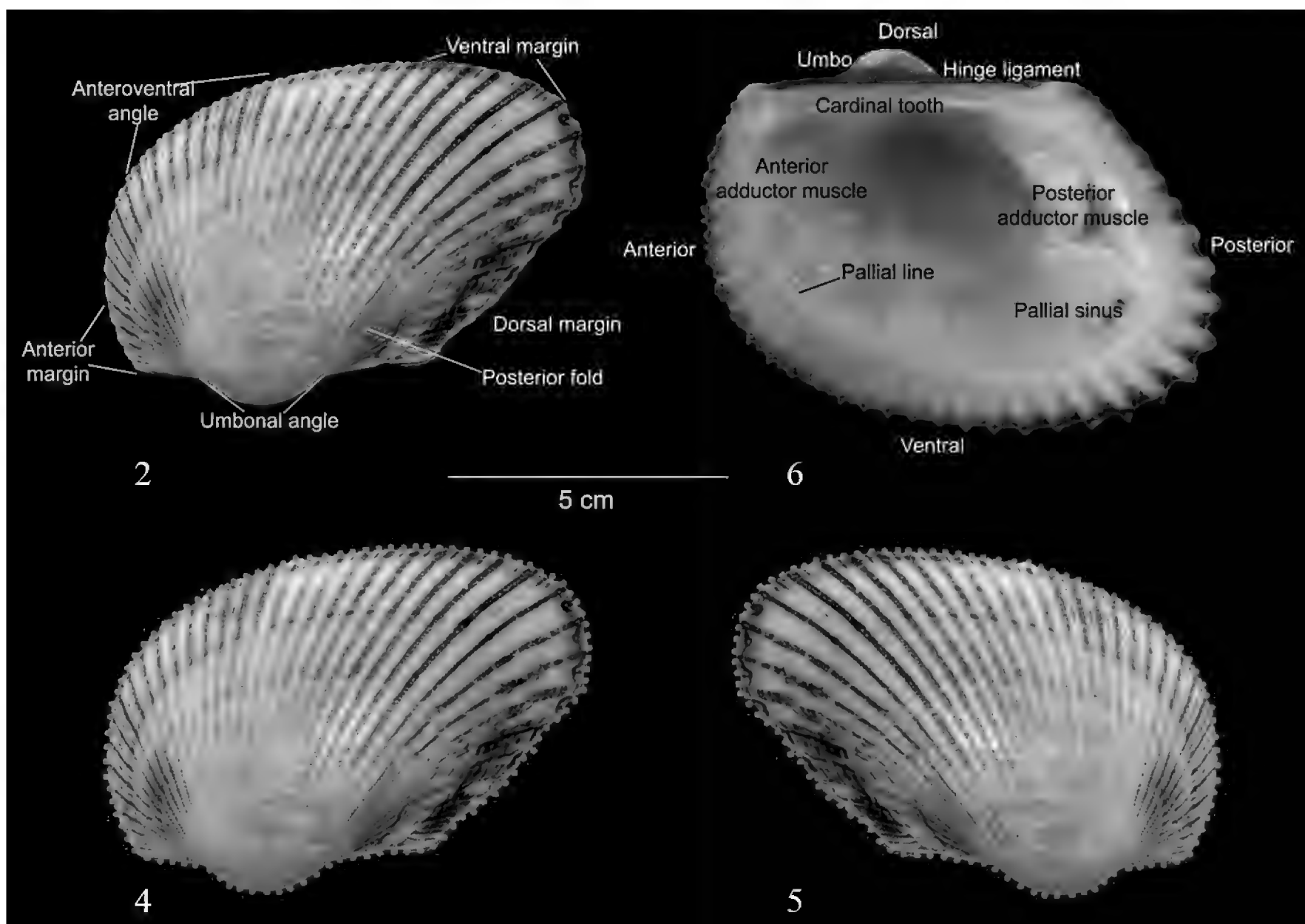
Bivalves are considered as bioindicators of the coastal ecosystem. As bioindicators, they can serve as functional measures of exposure to various stressors which help to detect early warning system declines in environmental quality and population health (Adams et al., 2004). In this study, we hypothesized that the varying anthropogenic disturbances brought about by the continuous destruction in mangrove ecosystem and improper disposal of residential wastes in the intertidal areas of Mar-

gosatubig have contributed to the deterioration of the quality of the habitat subjecting *A. oceanica* to ecological stress, thereby, promoting morphological variation in the shell shapes of this species.

Herewith, significant variations were observed in the shell shape of the left and right valves of *A. oceanica* between the two populations based from the results of MANOVA (Table 1). Thin plate splines of the mean shell shapes of *A. oceanica* between the two populations show visual illustrations where the variations could be observed (Figs. 6, 7). The distribution of individuals among the two populations of *A. oceanica* in the CVA plot shows how each population differs in terms of its shell shape (Fig. 8). It was clear from these results that both valves of *A. oceanica* exhibited shape variations among the two populations. Such variations are characterized by major variances in the umbonal and anteroventral angles and in the dorsal, anterior and ventral margins of the outer shell both in the left and right valves.

Between populations, left valves in Tulog-bato have expanded umbonal angle and slightly curved anteroventral angle while those in Samboang have compressed umbonal angle and pronouncedly curved anteroventral angle. On one hand, right valves in Tulog-bato population have largely expanded umbonal angle and pronouncedly curved anteroventral angle while those in Samboang population have largely compressed umbonal angle and outwardly protruding anteroventral angle. In the inner surface of bivalve shell, a mark called the pallial line lies in its surface more or less parallel with the anteroventral angle, thus, the variation observed in the anteroventral angle of *A. oceanica* could be affected by the differences in the pallial line of the inner valve (Markus, 2010).

Noticeably, the position of the outline in the left valve along the anterior margin among Tulog-bato population bends closer to the posterior fold of the shell resulting to shorter ventral margin and compressed dorsal margin compared to the elongated



Figures 2–5. Image of *A. oceanica* showing its (Fig. 2) outer and (Fig. 3) inner left valve and the outline in the (Fig. 4) left valve and (Fig. 5) right valve.

ventral margin and expanded dorsal margin of Samboang population since its anterior margin bends away to the posterior fold of the shell. In bivalve shells, anterior portions are shorter than the posterior (Tan et al., 2015). The same condition was observed in the anterior and dorsal margins of the right valves in Samboang population, thus the position of the outline in these margins are affected which move closer to the posterior fold making its ventral margin tightly compressed compared to the elongated ventral margin of Tulog-bato population since its dorsal and anterior margins bend away to the posterior fold.

The CVA scatter plot was produced from relative warp scores based on the pooled populations of *A. oceanica*. As shown in Figure 4, it illustrates the overlapping in the shell shape of the left and right valves of *A. oceanica* among the two populations, indicating that some individuals of *A. oceanica* have shown shell shape similarities in certain morphological aspects and that shell shape variations occurred herein can be attributed to the morphological distinctness of the individuals shell shape examined within population which have contributed significantly to the shape variances between populations (Peñaredondo & Demayo, 2017; Madjos & Demayo, 2018).

Disparities in the shell shapes were further visualized using the two varying deviated transformation grids: the negatively (-) and positively (+) deviated grids. Each deviation represents one or more population that tend towards the negative or positive deviation or near to the mean/consensus deviation of the morphological shape. Relative distribution of the variances are projected as boxplot that provides decisive criterion in selecting which population best assumes the form with respect to the mean shape (Sepe & Demayo, 2017). The variations observed using the method of relative warps obtained three (3) and four (4) significant relative warp scores for the left and right valves, respectively. The variations are shown in the form of boxplots, consensus morphology and frequency histograms for the left and right valves (Figs. 9, 10). The descriptions of the shell shape variation based on the significant RW scores in the pooled population of *A. oceanica* are discussed in Table 2.

In the left valve, the range of the boxplot of RW1 in Tulog-bato population spreads along the negative axis while Samboang population slightly

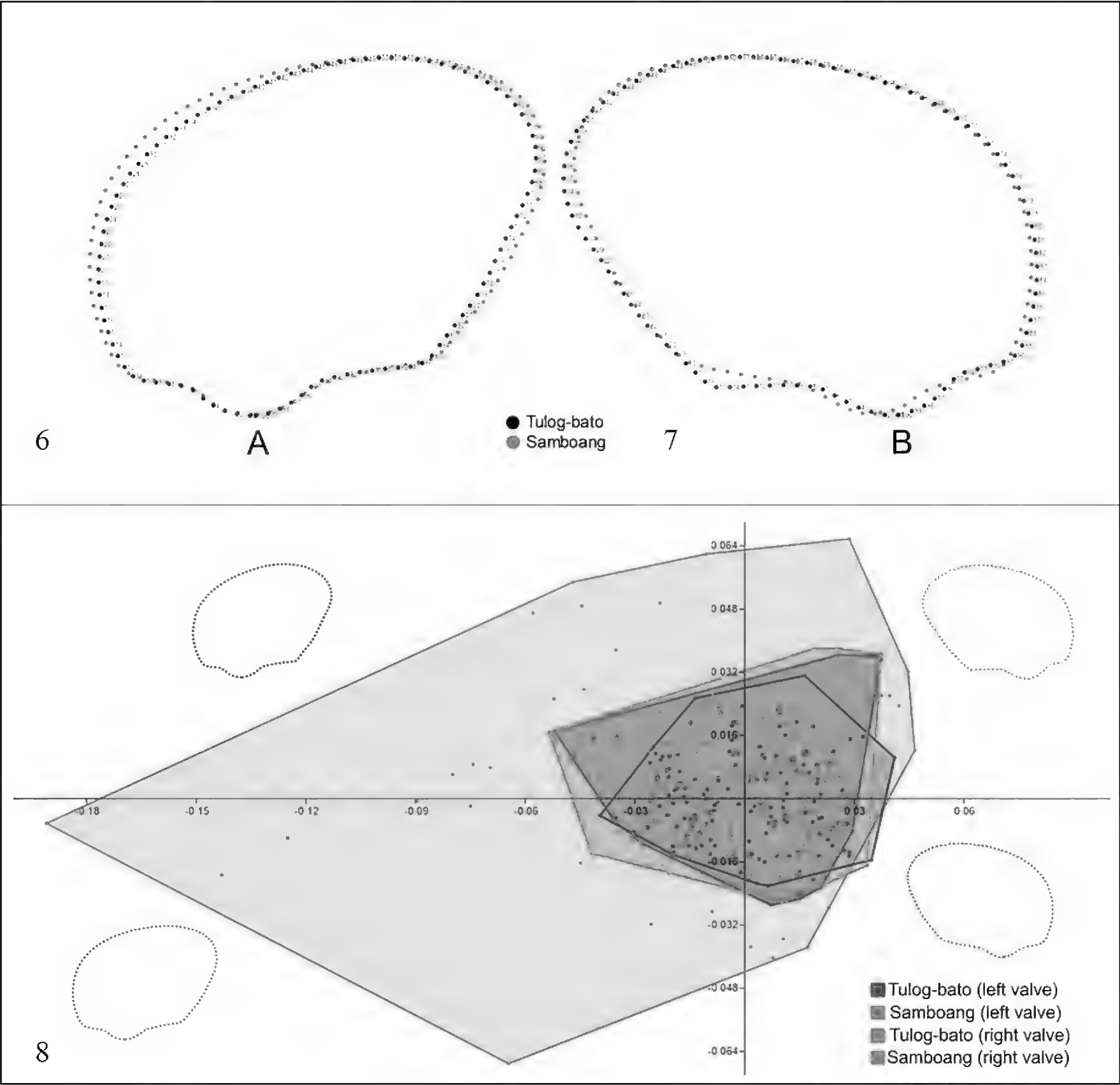
spreads along the positive axis which indicates that Tulog-bato population resembles the morphology explained in the negative axis while Samboang population reflects the morphology explained in positive axis. In both populations, the range of the boxplots of RW2 deviates towards negative axis while the range of boxplots of RW3 deviates towards positive axis. For the right valve, the range of the boxplot of RW1 in Tulog-bato population is found lying on the positive axis while Samboang population lies slightly along the negative axis which indicates that Tulog-bato population resembles the morphology explained in the positive axis while Samboang population reflects the morphology explained in negative axis. In both populations, the range of the boxplots of the RW2 and RW3 are skewed along the negative axis while the boxplot of the RW4 is skewed in positive axis.

Further analysis in the shell shapes of *A. oceanica* within population in terms of its symmetry was done through Procrustes Two-Way, Mixed-Model ANOVA to quantitatively determine the asymmetry levels in *A. oceanica* (Table 3). In both populations, the Individuals x Sides interaction yield significant p-value ($p < 0.001$), suggesting that the differences in the shapes between the left and right valves can be attributed to the failure of the effect of individual valves to be the same from side to side. Thus, this indicates fluctuating asymmetry in *A. oceanica* population. However, a considerably higher significant FA value was reflected in Samboang population ($F = 1.8904$, $p = 0.0000$) compared in Tulog-bato population ($F = 0.9572$, $p = 0.0000$), this implies that two different populations might have experienced varying ecological stress in their respective habitat and that it could be argued that Samboang populations are more ecologically stressed compared to the Tulog-bato populations (Palmer, 1994). The measured asymmetry in *A. oceanica* herein supports the idea that the valves of *Anadara* species are inequivalve wherein the left valves are usually larger than the right valves (Finogenova et al., 2013; Strafella et al., 2018). This random deviation in the symmetry of an organism such as in the case of *A. oceanica* has been hypothesized to be the result of the genome to protect the organism against stressors during development (Swaddle, 2003).

As illustrated by the principal components, the red dots in the grid represent the morphological landmarks used while the blue arrows symbolize

Valves	Wilk's lambda	Pillai trace	df1	df2	F	<i>p</i> value
Left valve	0.6028	0.3972E-08	4	175	28.83	2.0830E-18*
Right valve	0.4469	1.474E-08	4	175	54.14	1.2263E-29*
*Significant at $\alpha=0.05$						

Table 1. Results of Multivariate Analysis of Variance based on significant relative warp scores for significant variation in the shape of the left and right valves of *A. oceanica* between the two populations.



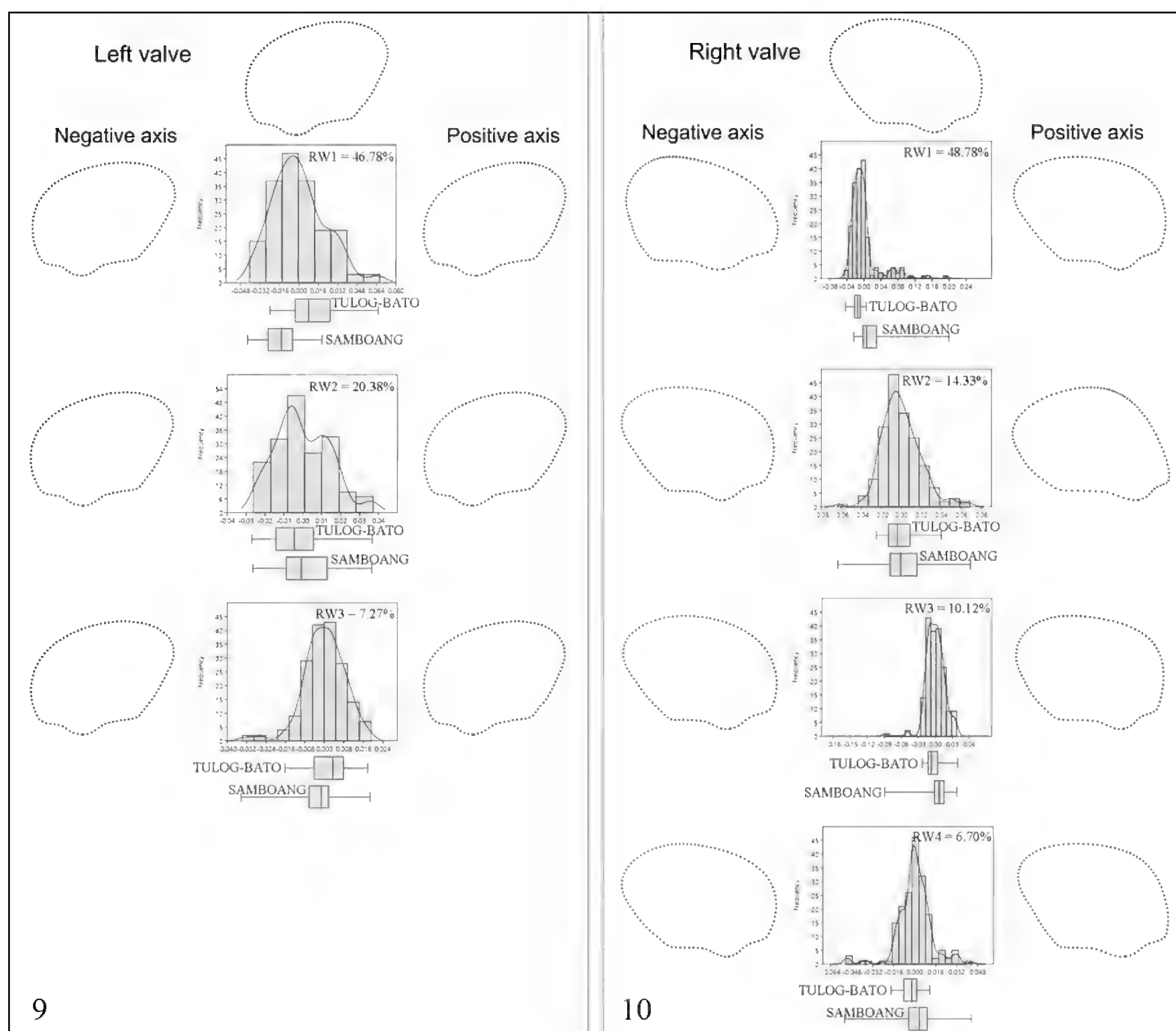
Figures 6, 7. Conchological mean shape variations of the (Fig. 6) left and (Fig. 7) right valves of *A. oceanica* between the two populations. Figure 8. Canonical Variate Analysis scatter plot showing the distribution of shell shapes between the two populations of *A. oceanica* based on significant relative warp scores.

Relative warp	Left valve	Right valve
RW1	Variation accounts about 46.78% (−) The umbonal angle is compressed while the anteroventral angle is pronouncedly curved. The dorsal and anterior margins bend closer to the posterior fold making its ventral margin elongated. (+) The umbonal angle is expanded while the anteroventral angle is slightly curved. The dorsal and anterior margins bend away to the posterior fold resulting to shortened ventral margin.	Variation accounts about 48.78% (−) The umbonal angle is largely expanded while the anteroventral margin bends inward. The dorsal and anterior margins bend away to the posterior fold making its ventral margin compressed. (+) The umbonal angle is compressed while the anteroventral angle is pronouncedly curved. The dorsal and anterior margins bend closer to the posterior fold resulting to elongated ventral margin.
RW2	Variation accounts about 20.38% (−) The umbonal angle bends towards dorsal margin while the anteroventral angle curved pronouncedly. The anterior margin bends closer to the posterior fold resulting to compressed dorsal margin and shortened ventral margin. (+) The umbonal angle bends towards anterior margin while the anteroventral angle curved slightly. The anterior margin bends away to the posterior fold making its dorsal margin expanded and ventral margin elongated.	Variation accounts about 14.33% (−) The umbonal angle is compressed while the anteroventral angle protrudes outward. The dorsal and anterior margins are shortened and bend closer to the posterior fold making its ventral margin elongated and it protrudes outward. (+) The umbonal angle is tightly compressed while the anteroventral angle and ventral margin bend inward. Anterior margin is tightly compressed away to the posterior fold making its dorsal margin elongated.
RW3	Variation accounts about 7.27% (−) The umbonal angle is expanded while the anteroventral angle is compressed. The dorsal margin slightly bends towards the posterior fold making its anterior margin pronouncedly curved and its ventral margin elongated. (−) The umbonal angle is expanded while the anteroventral angle is curved. Anterior margin bends away to the posterior fold making its dorsal margin slightly compressed and its ventral margin elongated.	Variation accounts about 10.12% (−) The umbonal angle is expanded while the anteroventral angle is curved. Anterior margin bends away to the posterior fold making its dorsal margin slightly compressed and its ventral margin elongated. (+) The anteroventral angle is shortened and pronouncedly curved. The umbonal angle and anterior margin are tightly compressed to each other resulting to largely expand dorsal margin and elongated ventral margin.
RW4		Variation accounts about 6.70% (−) The umbonal angle is compressed. While the anteroventral angle curved pronouncedly. The dorsal and anterior margins bend closer to the posterior fold making its ventral margin compressed. (+) The umbonal angle is largely expanded while the anteroventral angle bends inward and shortened. The ventral margin compressed tightly while the dorsal margin bends inward and the anterior margin protrudes outward.

Table 2. The shell shape variations observed in left and right valves of the pooled populations of *A. oceanica* as outlined by the significant relative warps.

the magnitude of the fluctuation (Figs. 11, 12). PCA revealed that the dominant features of variation related to FA in *A. oceanica* populations from both sites were associated with the deformations in the umbonal and anteroventral angles and in the dorsal, anterior and ventral margins of the outer shell. The percentage values of PCA represent the level of variability in the data wherein PC1 elucidates vec-

tors at landmarks showing the magnitude and direction of the displaced landmark while the PC2 explains the variance via the thin plate splines, an interpolation function that models change between landmarks from the data of changes in coordinates of landmarks (Marquez, 2014). Herewith, *A. oceanica* population in Samboang (71.62%) exhibited higher level of variability compared in Tulog-bato



Figures 9, 10. Relative warps showing the boxplot, consensus morphology and the frequency histogram of shell shape variability of the (Fig. 9) left and (Fig. 10) right valves of *A. maculosa* from the two populations.

population (54.72%) based on the overall variation exhibited by PC1 and PC2.

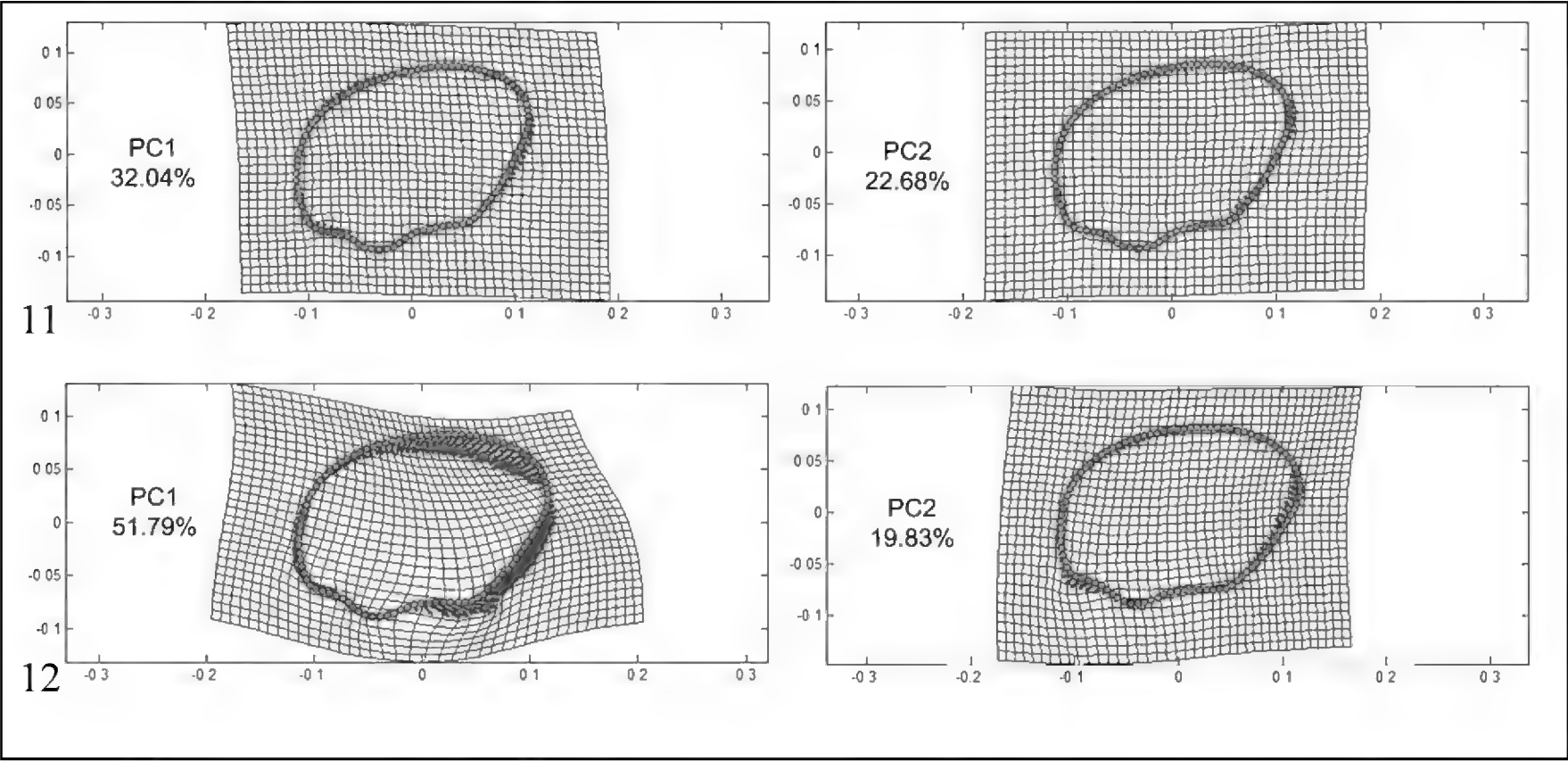
The causes of variations in the shell shapes of bivalves have been the focus of so many debates and for *A. oceanica* in particular, it should still be subjected to further studies. However, in this case, there could be many underlying factors that may have shaped variations within and between populations. Taking the results as a whole, it was clear that the differences in the shapes between the left and right valves of *A. oceanica* otherwise known as fluctuating asymmetry (FA) was the cause of shell shape variation within population that contributed significantly to the variation between populations. FA is defined as random deviations from

perfect symmetry of the morphology of an organism (Palmer, 1994). The variations within and between populations of *A. oceanica* could be genetic in nature resulting to different tolerance to stress. Populations of this species might have experienced developmental perturbations early in life in their respective habitat which resulted to the deviations from bilateral symmetry (Borlaza & Tabugo, 2018).

Based on field scientific observation during the sampling period, Tulog-bato and Samboang displayed some anthropogenic disturbances. In Tulog-bato, human activities such as cutting of mangroves for fuel wood and burning of mangroves for charcoal making are some of the disturbances that con-

Effects	SS	df	MS	F	p value
<i>Tulog-bato population</i>					
<i>Individuals</i>	0.0163	5684	0	0.675	0.0000***
<i>Sides</i>	0.0346	196	0.0002	41.5773	0.0000***
<i>Individuals x Sides</i>	0.0241	5684	0	0.9572	0.0000***
<i>Measurement Error</i>	0.1043	23520	0	---	---
<i>Samboang population</i>					
<i>Individuals</i>	0.0828	5684	0	0.8418	0.0000***
<i>Sides</i>	0.0697	196	0.0004	20.553	0.0000***
<i>Individuals x Sides</i>	0.0984	5684	0	1.8904	0.0000***
<i>Measurement Error</i>	0.2154	23520	0	---	---

Table 3. Results of Procrustes Two-Way, Mixed Model Analysis of Variance of the body symmetry of *A. oceanica* from the two populations. Note: Individuals = shape variation, Sides = directional asymmetry; Individuals x Sides interaction = fluctuating asymmetry; ***p<0.001- Highly significant, ns- Statistically insignificant (p>0.05); Significance was tested with 99 permutations.



Figures 11, 12. Deformation grids of shell shapes related to fluctuating asymmetry in *A. oceanica* from Tulog-bato (Fig. 11) and Samboang populations (Fig. 12) based from the first two principal components.

tributed to the destruction of this mangrove estuarine ecosystem. Furthermore, large amount of pollution brought by residential wastes is prevalent in Samboang which are directly disposed the intertidal zones due to the residential houses along the shore and this is evident by the various litter that is frequently found scattered in the coastline such as plastic bottles, plastic sachets and diapers. These

anthropogenic disturbances, among others, are the results of the growth of human population (Behera et al., 2014). As *A. oceanica* populations experienced these disturbances in these areas, they could develop an adaptation either to change its growth form or improve alternative phenotypes to adapt in its current habitat conditions which in return could lead to ecological plastic responses where changes

in the structure of the shells are the first visible reflections (Qonita et al., 2015). When the habitat is disturbed such as that of in Tulog-bato and Samboang, it leads to inability of an organism to moderate its development against genetic or environmental conditions (developmental instability) (Daloso, 2014). Such development cannot be restored to the original pathway causing slight random deviations in the symmetry and eventually increase phenotypic variations of the organism (Trono et al., 2015).

CONCLUSIONS

The use of outline-based geometric morphometrics showed significant variations in the shell shapes of the outer left and right valves between populations of *A. oceanica*. Although, these variations should be further studied in order to elucidate their sources. Further investigations revealed that the differences in the shapes between the left and right valves of *A. oceanica*, which is known as fluctuating asymmetry, were the cause of shell shape variation within populations that contributed significantly to the variation between populations. This study clearly proved that shell shape variation does not only occur in geographically isolated populations, it could also occur in neighbouring populations such as that of in Tulog-bato and Samboang. It is hypothesized that shell shape variation is an adaptive strategy of bivalves in response to its current ecological conditions. Thus, shell shape variations in *A. oceanica* populations may have implications to habitat adaptation which can help in understanding the nature of this species especially those inhabiting in the intertidal zones of Margosatubig, Zamboanga del Sur, Philippines.

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Contribution to the knowledge of Hymenoptera from the Aeolian Archipelago (Sicily), emphasizing Aculeata

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ABSTRACT

This study provides the first contribution to the knowledge of the Order Hymenoptera, emphasizing Aculeata, for the Aeolian archipelago, based on recent field investigations and examination of several collections. A total of 169 species belonging to 19 families are recorded: Evaniidae (1 species), Aulacidae (2 species), Gasteruptiidae (3 species), Ichneumonidae (1 species), Leucospidae (1 species), Chrysididae (8 species), Tiphidae (3 species), Scoliidae (6 species), Mutillidae (13 species), Pompilidae (6 species), Vespidae (14 species), Sphecidae (6 species), Crabronidae (24 species), Formicidae (14 species), Colletidae (4 species), Andrenidae (8 species), Halictidae (29 species), Megachilidae (12 species), Apidae (14 species). Most part of species are newly recorded for the Aeolian Archipelago, the following being new records for Sicily: *Dryudella esterinae* Pagliano, 2001, *Nysson quadriguttatus* Spinola, 1808, *Miscophus aetoni* Saunders, 1903, *Miscophus lusitanicus* Andrade, 1952, *Cerceris circularis dacica* Schletterer, 1887 (Crabronidae), and *Lasioglossum (Dialictus) semilucens* (Alfken, 1914) (Halictidae); *Miscophus lusitanicus* is also newly recorded for Italy. Combining the available data, a total of 218 species of Hymenoptera are currently known for the Aeolian Archipelago. The Hymenoptera fauna of these islands is dominated by widespread Mediterranean or West Palaearctic species, and most of them are also found in the Western Mediterranean Basin. The study briefly highlights some key points regarding biogeographical and conservation of this group and its significant role in the management of ecosystems in the Aeolian Archipelago.

KEY WORDS Aeolian Archipelago; Sicily; Hymenoptera; faunal list.

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INTRODUCTION

The Aeolian Islands have great importance in terms of environmental and biological heritage, and have been recognized by UNESCO as World Heritage Site. This archipelago harbors five protected areas and several sites of the Nature 2000 network,

and has been also proposed as National Park in 2007, although that has not yet been followed by a real institution. Both fauna and flora of these islands are characterized by the occurrence of many species of biogeographical and conservation interest, including some endemics. The faunal knowledge may be considered exhaustive for vertebrates, while several

groups of invertebrates remain still less investigated (Lo Cascio, 2017).

Among them, the hymenopterans have been only poorly studied despite their ecological importance, e.g., for the pollination of wild plants and crops as well as for the biological control of many groups of Arthropods. Data on the Hymenoptera from these islands are scanty and scattered in a wide literature, which includes monographs, collection's and taxonomic reviews (Santschi, 1927, 1934; Baroni Urbani, 1964, 1971; Warncke, 1981; Pagliano, 1987; Gayubo et al., 1988; Matteini Palmerini, 1992; Pagliano & Nobile, 1993; Ebmer, 1995; Olmi, 1999; Sanetra et al., 1999; Czösz & Schulz, 2010; Vicidomini et al., 2005; Boni Bartalucci, 2012; Pavesi & Rosa, 2013; Borowiec et al., 2015; Turrisi et al., 2015; Seifert, 2016; Korenko, 2017; Scupola, 2019), the "Checklist of Italian fauna" (Comba & Comba, 2005; Generani et al., 2005; Olmi, 2005; Strumia, 2005), papers related to apiculture and/or biological control (Monastero & Genduso, 1964a, 1964b; Monastero, 1965; Monastero & Delaonoue, 1965, 1966a, 1966b; Genduso & Mineo, 1974; Dall'Olio et al., 2008; Daane & Johnson, 2010; Bouga et al., 2011; Tenore et al., 2012; Muñoz et al., 2014; Utzeri et al., 2018) and faunal papers concerning Italian peninsular and insular areas or other islands (Kutter, 1927; Baccetti, 1967; Focarile, 1972; Nobile & Turrisi, 1996; Lo Cascio et al., 1998; Mei, 1998, 2008; Turrisi, 1999; Lo Cascio & Navarra, 2003; Borsato & Turrisi, 2004; Lo Cascio, 2004, 2015; Lo Cascio & Romano, 2004; Lo Cascio et al., 2006; Jucker et al., 2008; Ceccolini & Barbagli, 2014; Queiroz & Alves, 2016; Turrisi & Altadonna, 2017; Korenko & Di Giovanni, 2019), while just few papers are specifically referred to the fauna of the Aeolian Archipelago, although not exclusively dedicated to Hymenoptera (Costantino, 1937; Lo Cascio, 2004).

The aim of this paper is to update the knowledge of the Hymenoptera of the Aeolian Archipelago through the study of the material from several private and museum collections and that collected during recent field surveys.

MATERIAL AND METHODS

Study area

The Aeolian Archipelago (Fig. 1) lies between

38°21'54" and 38°48'40" latitude North and 14°20'35" and 15°14'70" longitude East of Greenwich, in the southern Tyrrhenian Sea. It includes seven main islands (Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi and Panarea) whose surface ranges from 37.29 to 3.34 km², and several uninhabited islets and rocks. The southernmost island, Vulcano, is located 20 km from the Sicily, while the northernmost, Stromboli, is only 55 km far from the Italian Peninsula (Capo Vaticano). The origin of this volcanic archipelago is strictly linked to the subduction processes related to the convergence between African and Euro-Asiatic plates. The islands are disposed along a semi-arc and represents the top of a wide volcanic system, that includes also several sea-mounts. The beginning of the activity in this area is dated back about 1,000,000 years ago, but the actual islands emerged during the last 300,000 years and some of them (for instance, Alicudi, Stromboli and Vulcano) are rather "young", with an estimated age of less than 100,000 years. Currently there are only three active volcanoes, namely Stromboli, Gran Cratere or La Fossa on Vulcano and a sub-marine crater off the eastern coast of Panarea. The first human settlements in the archipelago are dated to the end of 6th millennium B.C., hence the islands have undergone to a long-term anthropization; this trait plays a significant role in their actual landscape, that is widely characterized by terraced agricultural lands, mostly abandoned since the dramatic economical crisis that involved the local communities between late 19th and the first half of the 20th century. Currently these areas host a complex mosaic of xeric grasslands, garrigues and maquis, with more mature and structured spots of the latter occurring on the top and the inner part of some islands (Salina, Lipari, Filicudi) (Lo Cascio, 2017).

Materials

Data provided in the present paper include the records given in literature and those obtained from the museum and private collections of the authors and several colleagues. The most part of the field surveys was done on the islands of Lipari and Vulcano, but some investigations were carried out on other islands. The specimens were gathered mainly through traditional collecting-methods (hand net), but also yellow-pan traps, Moericke traps, wine

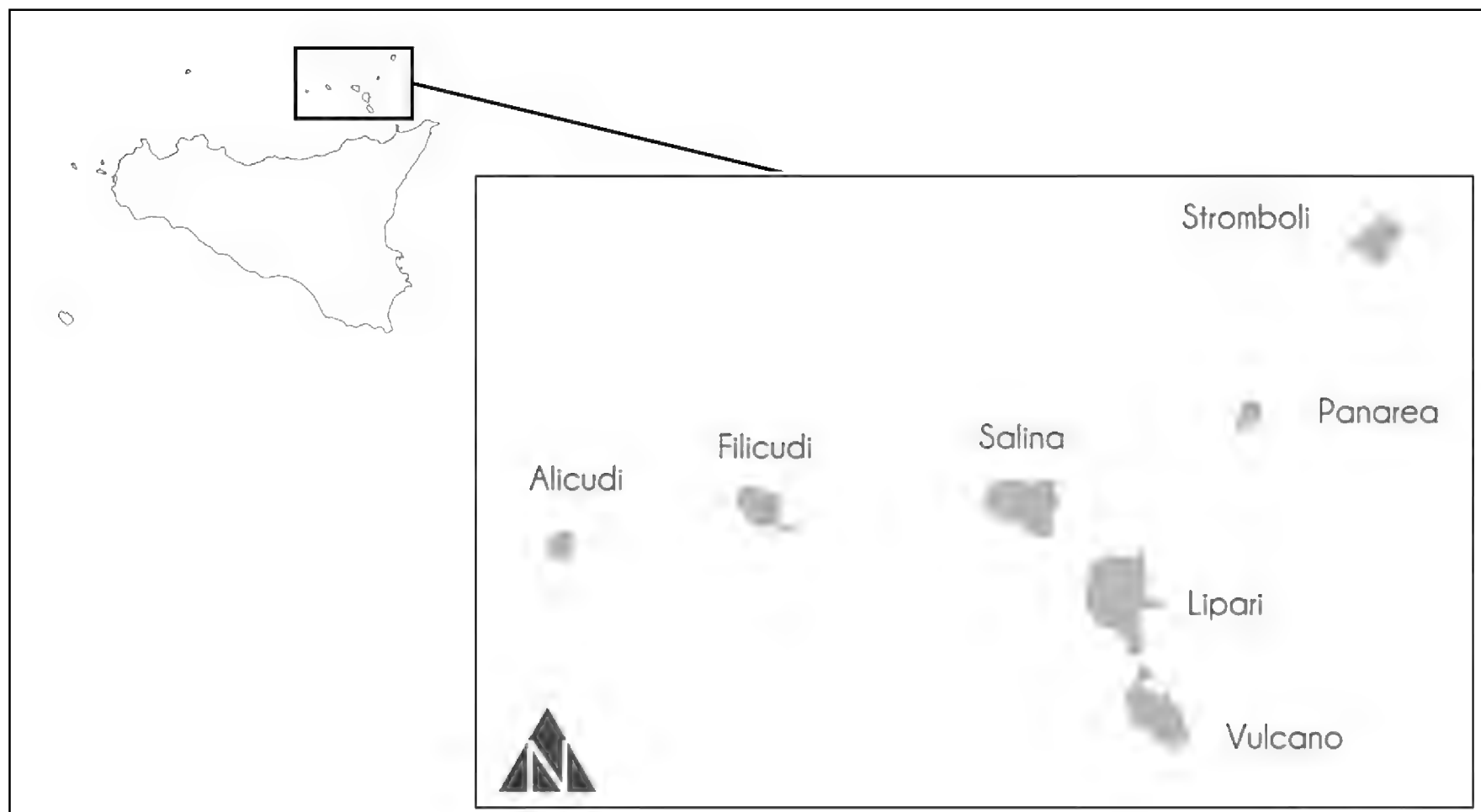


Figure 1. Localization of the study area.

traps and light traps have been used. For each species treated, we provide:

- 1) list of material examined;
- 2) distribution;
- 3) remarks, including eventual previous records.

The list of species is arranged according to the “Checklist della Fauna d’Italia” (Ruffo & Stock, 2005).

ACRONYMS. GAC: Giovanni Altadonna, Messina, Italy; WBC: Walter Borsato, Verona, Italy; DSCC: Dipartimento Scienze Biologiche, Geologiche e Ambientali, Università di Catania, Sezione Biologia Animale, Italy; PLCC: Pietro Lo Cascio, Lipari, Italy; MMC: Maurizio Mei, Roma, Italy; RAC: Museo Regionale di Terrasini (Coll. R. Alliata), Terrasini (Palermo), Italy; PNC: Pietro Niolu, Sassari, Italy; VNC: Vittorio Nobile, Ragusa, Italy; MRC: Marcello Romano, Capaci (Palermo), Italy; MSC: Marco Selis, Viterbo, Italy; GFTC: Giuseppe Fabrizio Turrise, Pedara (Catania), Italy; CVC: Carlo Violani, Milan, Italy.

RESULTS

A total of 169 species are herein recorded for the Aeolian Archipelago, belonging to 19 families:

Evaniidae (1 species), Aulacidae (2 species), Gasteruptionidae (3 species), Ichneumonidae (1 species), Leucospidae (1 species), Chrysididae (8 species), Tiphiidae (3 species), Scoliidae (6 species), Mutillidae (13 species), Pompilidae (6 species), Sphecidae (6 species), Crabronidae (24 species), Vespidae (14 species), Formicidae (14 species), Colletidae (4 species), Andrenidae (8 species), Halictidae (29 species), Megachilidae (12 species), Apidae (14 species). A summary of the distribution of Hymenoptera on the Aeolian Archipelago, including records from literature, is provided in Table 1.

Faunal list

EVANIIDAE

Zeuxevania splendidula (Costa, 1884) (Fig. 2)

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI. 1997, 3 females, G.F. Turrise leg. and det. (GFTC).

DISTRIBUTION. South European.

REMARKS. New for the Aeolian Archipelago.

AULACIDAE

Pristaulacus galitae (Gribodo, 1879)

EXAMINED MATERIAL. Vulcano: 28.VI.18. VII. 2008, 2 males, 2 females, M. Mei leg., G.F. Turrisi det. (GFTC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago, known from many other Mediterranean islands, e.g., Maltese Islands (Turrisi, 2007; Turrisi & Rattu, 2019).

Pristaulacus lindae Turrisi, 2000 (Fig. 3)

EXAMINED MATERIAL. Vulcano: 28.VI.-18.VII. 2008, 1 female, M. Mei leg., G.F. Turrisi det. (GFTC).

DISTRIBUTION. South West European.

REMARKS. New for the Aeolian Archipelago. Described from Sicily (Turrisi, 2000), subsequently recorded from other localities from Eastern Sicily (Turrisi, 2007), it has recently been recorded from Iberian Peninsula (Carbonell-Font & Turrisi, 2017).

GASTERUPTIIDAE

Gasteruption assectator (Linnaeus, 1758)

EXAMINED MATERIAL. Lipari: Castellaro, 23. VI. 1998, 1 female, B. Carletti, B. Cecchi, L. Dapporto, P. Lo Cascio, C. Moreno leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Holarctic.

REMARKS. New for the Aeolian Archipelago.

Gasteruption erythrostomum (Dahlbom, 1831)

EXAMINED MATERIAL. Lipari: Urnazzo, 2. VI. 1997, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. European.

REMARKS. New for the Aeolian Archipelago.

Gasteruption jaculator (Linnaeus, 1758)

EXAMINED MATERIAL. Lipari: Pianoconte, 7.

VII. 1999, 1 female, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

ICHNEUMONIDAE

Eutanyacra picta (Schrank, 1776) (Fig. 4)

EXAMINED MATERIAL. Vulcano: Piano, 4. VI. 1997, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Palaearctic and Oriental.

REMARKS. New for the Aeolian Archipelago.

LEUCOSPIDAE

Leucospis gigas Fabricius, 1793 (Fig. 5)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI. 1997, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. European Asian (southern part). The record from Nearctic requires confirmation.

REMARKS. New for Lipari, previously observed and photographed in Stromboli on 12.06.2011 (https://www.naturamediterraneo.com/forum/topic.asp?TOPIC_ID=146201). It is primarily associated with Megachilidae (Noyes, 2019), and among the known hosts there are two large *Megachile* (*Chalicodoma*): *M. (C.) parietina* (Geoffroy, 1785) and *M. (C.) sicula* Rossi, 1792, both collected in Lipari, the former one in the same place and in the same time along a dry-stone wall.

CHRYSIDIDAE

Hedychridium* cf. *mediocrum Linsenmaier, 1987

EXAMINED MATERIAL. Salina: Monte Fossa delle Felci, VII.2017, P. Lo Cascio leg., P. Rosa det. (PLCC).

DISTRIBUTION. South European.

REMARKS. New for the Aeolian Archipelago and Sicily.

***Hedychrum cf. micans* ssp. *europaeum* Lin-senmaier, 1959**

EXAMINED MATERIAL. Salina: Monte Fossa delle Felci, 22.V.2009, P. Lo Cascio & F. Grita leg., P. Rosa det. (PLCC).

DISTRIBUTION. West European.

REMARKS. New for the Aeolian Archipelago.

***Holopyga fervida* (Fabricius, 1781) (Fig. 6)**

EXAMINED MATERIAL. Alicudi: VII.2013, 2 females, P. Lo Cascio & F. Grita leg., P. Rosa det. (PLCC). Vulcano, crater, VII.2016, 1 female, P. Lo Cascio leg., P. Rosa det. (PLCC); Lipari, Palmeto, V.2016, 1 female, P. Lo Cascio leg., P. Rosa det. (PLCC). Panarea, Soldata, 20.V.2009, 1 female, P. Lo Cascio & F. Grita leg., P. Rosa det. (PLCC). Stromboli, Nel Cannestra, V.2016, 1 female, P. Lo Cascio leg., P. Rosa det. (PLCC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Pseudomalus auratus* (Linnaeus, 1758)**

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC). Lipari: Palmeto, 20.VI.1998, 1 female, B. Carletti et al. leg., G.F. Turrisi det. (PLCC). Lipari: Monte Guardia, IV.2009, 3 females, P. Lo Cascio & F. Grita leg., reared from wood, G.F. Turrisi det. (PLCC).

DISTRIBUTION. Holarctic.

REMARKS. Recently recorded from Lipari by Pavesi & Rosa (2013).

***Chrysis* cf. *auriceps* Mader, 1936**

EXAMINED MATERIAL. Panarea: Soldata, 230 m a.s.l., 21.VIII.2015, 2 specs., G. Altadonna leg., yellow-pan trap, P. Rosa det. (GAC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

***Chrysis cerastes* Abeille De Perrin, 1877 (Fig. 7)**

EXAMINED MATERIAL. Salina: Monte Fossa delle

Felci, VII.2017, 1 female, P. Lo Cascio leg., P. Rosa det. (PLCC).

DISTRIBUTION. South European.

REMARKS. New for the Aeolian Archipelago.

***Chrysis scutellaris* Fabricius, 1794**

EXAMINED MATERIAL. Filicudi: Capo Graziano, 26.VI.2016, 1 male, P. Lo Cascio leg., P. Rosa det. (PLCC).

DISTRIBUTION. West European.

REMARKS. New for the Aeolian Archipelago.

***Pseudochrysis neglecta* (Shuckard, 1837)**

EXAMINED MATERIAL. Vulcano: Piano, 20. IV. 2009, 1 spec., P. Lo Cascio & F. Grita leg., P. Rosa det. (PLCC).

DISTRIBUTION. European Asian

REMARKS. New for the Aeolian Archipelago.

TIPHIIDAE***Tiphia lepeletieri* Berland, 1925**

EXAMINED MATERIAL. Lipari: Monte Chirica, 26. IX.1996, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC); Vallone Muria, VII.1999, 1 male, M-ericke trap, P. Lo Cascio leg., G.F. Turrisi det. (PLCC); Castellaro, IX.1998, 1 male, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Italian.

REMARKS. Known from Sicily (Boni Bartalucci, 2012, 2013), new for the Aeolian Archipelago.

***Meria dorsalis* (Fabricius, 1804) (Fig. 8)**

EXAMINED MATERIAL. Lipari: Urnazzo, 30. VII. 1996, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC); Chiesa Vecchia, 7.VII.1999, 2 females, on flowers of cultivated *Petroselinum*, G.F. Turrisi leg. and det. (GFTC). Vulcano: Piano, 330 m a.s.l., 18.VIII.2015, 1 female, G. Altadonna leg., G.F. Turrisi det. (GAC); 9-22.VIII.2015, 2 females, G. Altadonna leg., yellow-pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. European Asian.

REMARKS. Recorded from Lipari by Boni Bartalucci (2012), is newly recorded for Vulcano.

Meria tripunctata (Rossi, 1790)

EXAMINED MATERIAL. Lipari: Vallone Muria, VII.1999, 1 female, P. Lo Cascio leg., Moericke trap, G.F. Turrisi det. (PLCC). Vulcano: Piano, 330 m a.s.l., 13.VIII.2015, 1 female, G. Altadonna leg., G.F. Turrisi det. (GAC); 9-22.VIII.2015, 3 females, G. Altadonna leg., yellow-pan trap, M. Selis det. (GAC).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded from Lipari by Boni Bartalucci (2012), is newly recorded for Vulcano.

SCOLIIDAE

Megascolia (Regiscolia) maculata* ssp. *flavifrons (Fabricius, 1775)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI. 1997, 1 male, G.F. Turrisi leg. and det. (GFTC); Vulcano: Piani di Luccia, 2.VI.2012, 1 male, G. Altadonna leg. and det. (GAC).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari and Salina by Generani et al., (2005) and for Vulcano, as *Megascolia maculata* (Drury, 1773), by Ceccolini & Barbagli (2014).

Megascolia bidens (Fabricius, 1775)

EXAMINED MATERIAL. Vulcano: Piano, 2. VI. 2011, 2 males, G. Altadonna leg. and det. (GAC)

DISTRIBUTION. Mediterranean.

REMARKS. Recorded for Lipari and Vulcano by Generani et al. (2005).

Scolia hirta (Schrank, 1781)

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. South West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Scolia carbonaria (Linnaeus, 1767) (Fig. 9)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC). Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. South Italian Maghrebian.

REMARKS. New for the Aeolian Archipelago.

Colpa (Colpa) sexmaculata (Fabricius, 1781)

EXAMINED MATERIAL. Vulcano: Monte Aria, 405 m a.s.l., 16.VIII.2014, 2 males, G. Altadonna leg., G.F. Turrisi det. (GAC, MSC).

DISTRIBUTION. Southern Europe.

REMARKS. Previously recorded for “Stromboli, loc. Malpasseddu (Lipari, ME) 13.VII.2000, F. Barbagli & S. Lotti [leg.]” and “Lipari, Monte Guardia (ME) 25.VIII.1996, P. Lo Cascio [leg.]” by Ceccolini & Barbagli (2014), is newly recorded for Vulcano.

Dasyscolia ciliata (Fabricius, 1787)

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 10.VIII.2013, 1 male, G. Altadonna leg., G.F. Turrisi det. (GAC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

MUTILLIDAE

Bidecoloratilla leopoldina (Invrea, 1955)

EXAMINED MATERIAL. Lipari: Quattropani, 7. VI.1997, 1 male, 1 female, G.F. Turrisi leg. and det. (GFTC) (quoted in Turrisi, 1999, and Turrisi et al., 2015); Vallone Muria, IX.1995, VII-VIII.1996, 3.VI.1997, 3.VIII.1997, 9 males, 12 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Madoro, 21.VIII.1996, 25.II.1996, 8 males, 5 females, P. Lo Cascio & S. Pasta leg., P. Lo Cascio & M. Romano det. (PLCC); Falcone,

30.III.1997, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Timpone Ricotta, 3.VI.1997, 1 male, 6 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded as *Blakeius leopoldinus* (Invrea, 1955) for Lipari by Turrise (1999) and Lo Cascio & Romano (2004); for Salina and Vulcano by Lo Cascio (2015).

Myrmilla (Myrmilla) calva (Villers, 1789)

EXAMINED MATERIAL. Lipari: Capperio, 19.VII.1995, 2 females, P. Lo Cascio & S. Pasta leg., P. Lo Cascio & M. Romano det. (PLCC); Timpone Ospedale, 18.IV.1996, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Vallone Muria, VII.-VIII.1996, 3.VI.1997, 8 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Madoro, 21.VIII.1996, 3 females, P. Lo Cascio & S. Pasta leg., P. Lo Cascio & M. Romano det. (PLCC); Timpone Ricotta, VIII.1996, 3.VI.1997, 4.X.1997, 27.V.1998, 20.VI.1998, 1 male, 13 females, P. Lo Cascio leg. et al., P. Lo Cascio & M. Romano det. (PLCC). Vulcano: Capo Grillo, 27.V.1983, 1 female, M. Romano leg., P. Lo Cascio & M. Romano det. (MRC); Gran Cratere, 4.VI.1997, 2 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. European Mediterranean.

REMARKS. Recorded for Lipari and Vulcano by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

Ronisia brutia* ssp. *brutia (Petagna, 1787)
(Fig. 10)

EXAMINED MATERIAL. Lipari: Monte Sant'Angelo, 28.VI.1966, 1 female, V. Nobile leg., G.F. Turrise det. (quoted in Turrise, 1999); Capperio, 25.V.1996, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Palmeto, 10.VII.1996, 1 female, A. Nistri & S. Vanni leg., P. Lo Cascio & M. Romano det. (CVC); Quattropiani, 3.V.2001, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC). Filicudi, Zucco Grande,

6.V.2002, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari by Matteini Palmerini (1992) and Turrise (1999), Lipari and Filicudi by Lo Cascio & Romano (2004), Lipari, Vulcano, Salina, Filicudi and Panarea by Lo Cascio (2015).

Ronisia ghilianii (Spinola, 1843)

EXAMINED MATERIAL. Lipari: 3.X.1976, 1 female, B. Massa leg., P. Lo Cascio & M. Romano det. (MRC); Capperio, VII.1995, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Vallone Muria, VII.1995, 13.VIII.1996, 3.VI.1997, 4 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Timpone Ricotta, 3.VI.1997, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Palmeto, VIII.1998, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC). Panarea: Punta del Corvo, 26.V.2000, 1 female, P. Lo Cascio & C. Moreno Camacho leg., P. Lo Cascio & M. Romano det. (PLCC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded for Lipari and Panarea by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

Tropidotilla litoralis (Petagna, 1787)

EXAMINED MATERIAL. Lipari: 1 female, M.G. Di Palma leg., P. Lo Cascio & M. Romano det. (MRC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. European Mediterranean.

REMARKS. Recorded for Lipari by Lo Cascio et al., (1998), Lo Cascio & Romano (2004) and for Lipari and Vulcano by Lo Cascio (2015).

Nemka viduata* ssp. *viduata (Pallas, 1773)

EXAMINED MATERIAL. Lipari: Quattropiani, 7. VI. 1997, 1 female, G.F. Turrise leg. and det. (GFTC)

(quoted in Turrisi, 1999); Capperò, VII.1995, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Palmeto, 1 female, P. Lo Cascio & V. Pancioli leg., P. Lo Cascio & M. Romano det. (PLCC); Vallone dei Lacci, VIII.1995, 1 female, P. Lo Cascio & V. Pancioli leg., P. Lo Cascio & M. Romano det. (PLCC); Timpone Ricotta, 8.X.1996, 3.VI.1997, 3 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC). Vulcano: 1.VI.1956, 1 female, E. Di Napoli leg., P. Lo Cascio & M. Romano det. (RAC); 3-17.VII.1993, 1 female, M. Mei leg., P. Lo Cascio & M. Romano det. (MMC); Gran Cratere, 4.VI.1997, 4 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC, MRC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari by Turrisi (1999), for Lipari and Vulcano by Lo Cascio & Romano (2004) and for Stromboli and the above mentioned islands by Lo Cascio (2015).

Physetopoda pusilla (Klug, 1835)

EXAMINED MATERIAL. Lipari: Vallone Muria, 18.VII.1996, 13.VIII.1996, 3 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Fontanelle, 19.VIII.1996, 1 female, P. Lo Cascio & S. Pasta leg., P. Lo Cascio & M. Romano det. (PLCC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

Smicromyrme ausonia Invrea, 1950

EXAMINED MATERIAL. Lipari: Vallone Muria, 13.VIII.1996, 1 male, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Castellaro, 21.VIII.1999, 1 male, P. Lo Cascio & C. Moreno Camacho leg., P. Lo Cascio & M. Romano det. (PLCC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

Smicromyrme ruficollis (Fabricius, 1794)

EXAMINED MATERIAL. Lipari: S. Lucia, VIII.1996, 1 male (light trap), P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC); Fontanelle, 19.VIII.1996, 1 female, P. Lo Cascio & S. Pasta leg., P. Lo Cascio & M. Romano det. (PLCC); Vallone Muria, VIII-IX.1998, 7 males, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC). Vulcano: 3-17.VII.1993, 1 female, M. Mei leg., P. Lo Cascio & M. Romano det. (MMC); Monte Lentia, 4.VI.1997, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLCC). Stromboli: Scari, 24.VI.1998, 1 male (light trap), B. Carletti et al., leg., P. Lo Cascio & M. Romano det. (PLCC) (this material is quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. European.

REMARKS. Recorded for Lipari, Vulcano and Stromboli by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

Smicromyrme sulcisia Invrea, 1955

EXAMINED MATERIAL. Lipari: Capperò, VIII.1995, 1 female, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLC); Vallone Muria, VII-VIII.1996, 3.VI.1997, 1 male, 7 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLC). Vulcano: Monte Lentia, 4.VI.1997, 1 male, 4 females, P. Lo Cascio leg., P. Lo Cascio & M. Romano det. (PLC); Gran Cratere, 4.VI.1997, 22.VI.1998, 3 females, P. Lo Cascio et al. leg., P. Lo Cascio & M. Romano det. (PLC); Piano, 23.V.2000, 1 female, P. Lo Cascio and C. Moreno Camacho leg., P. Lo Cascio & M. Romano det. (PLC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. South European.

REMARKS. Recorded for Lipari and Vulcano by Lo Cascio & Romano (2004) as *S. ingauna* Invrea, 1958 (see also Lo Cascio, 2015).

Smicromyrme trinotata (A. Costa, 1858)

EXAMINED MATERIAL. Lipari: Vallone Muria, VII.1995, 1 male, P. Lo Cascio leg. and det. (PLC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. Sicilian Sardinian Corsican.

REMARKS. Recorded for Lipari by Lo Cascio & Romano (2004) as *S. prope melanolepis* (Costa, 1884) (see also Lo Cascio 2015).

Smicromyrme partita (Klug, 1835)

EXAMINED MATERIAL. Lipari: Vallone Muria, VII.1995, VII-VIII.1996, 14.X.1996, 3.VI.1997, 9female, P. Lo Cascio leg. and det. (PLC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. Mediterranean.

REMARKS. The species is recorded for Lipari as *Smicromyrme partita* sensu lato by Lo Cascio & Romano (2004) due to the lack of males, hence the identification needs further study for confirmation.

Dasylabris maura* ssp. *maura (Linnaeus, 1758)

EXAMINED MATERIAL. Lipari: Timpone Ricotta, 4.X.1997, 27.V.1998, 20.IV.1998, 1 male, 3 females, P. Lo Cascio leg. and det. (PLC) (quoted in Lo Cascio & Romano, 2004).

DISTRIBUTION. European.

REMARKS. Recorded for Lipari by Lo Cascio & Romano (2004), quoted in Lo Cascio (2015).

POMPILIDAE

Pompilus cinereus Fabricius, 1798 (Fig. 11)

EXAMINED MATERIAL. Vulcano: Monte Lentia, 4.VI.1997, 1 female, P. Lo Cascio leg., on sand, G.F. Turrisi det. (PLCC). Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 2 males, G. Altadonna leg., yellow-pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. European Maghrebian.

REMARKS. New for the Aeolian Archipelago.

Agenioideus ciliatus (Lepelletier, 1845)

EXAMINED MATERIAL. Lipari: Timpone Ricotta, 27.V.1998, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. European Anatolian.

REMARKS. New for the Aeolian Archipelago.

Anoplius viaticus (Linnaeus, 1758)

EXAMINED MATERIAL. Lipari: Quattropani, 6.VI.1997, 4 males, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Aporus bicolor Spinola, 1808 (Fig. 12)

EXAMINED MATERIAL. Lipari: Urnazzo, 30. VII. 1996, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC). Lipari: Quattropani, 6.VI.1997, 1 female, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. European Maghrebian Anatolian.

REMARKS. New for the Aeolian Archipelago.

Auplopus carbonarius (Scopoli, 1763)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC). Lipari: Castello environs, 8.VI.1997, 1 female, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. Palaearctic (introduced in North America).

REMARKS. New for the Aeolian Archipelago.

Priocnemis (Priocnemis) propinqua (Lepelletier, 1845)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1 female, G.F. Turrisi leg.-det. (GFTC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

VESPIDAE

Leptochilus (Neoleptochilus) regulus (Saunders, 1855)

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 male, M. Mei leg., W. Borsato det. (WBC).

DISTRIBUTION. West Palaearctic.

REMARKS. The material examined is quoted in Borsato & Turrisi (2004).

Stenodynerus fastidiosissimus* ssp. *fastidiosissimus (Saussure, 1855)

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 male, M. Mei leg., W. Borsato det. (WBC).

DISTRIBUTION. West Palaearctic.

REMARKS. The material examined is quoted in Borsato & Turrisi (2004).

Ancistrocerus auctus* ssp. *auctus (Fabricius, 1793)

EXAMINED MATERIAL. Lipari, 8.VI.1997, 1 male, G.F. Turrisi leg. (GFTC).

DISTRIBUTION. European Asian.

REMARKS. The material examined is quoted in Borsato & Turrisi (2004).

Ancistrocerus gazella (Panzer, 1798)

EXAMINED MATERIAL. Vulcano: VII.1993, 1 male, M. Mei leg., W. Borsato det. (WBC).

DISTRIBUTION. Palaearctic (introduced in North America and New Zealand).

REMARKS. The material examined is quoted in Borsato & Turrisi (2004).

Ancistrocerus longispinosus* ssp. *longispinosus (Saussure, 1855)

EXAMINED MATERIAL. Lipari: main town, 8.VI.1997, 1 female, G.F. Turrisi leg., W. Borsato det. (GFTC) (quoted in Borsato & Turrisi, 2004). Salina, 7.IV.1990, 1 female, M. Mei leg., W. Borsato det. (WBC) (quoted in Borsato & Turrisi, 2004). Vulcano: VII.1993, 1 female, M. Mei leg., W. Borsato det. (WBC) (quoted in Borsato & Turrisi, 2004); Piano, 330 m a.s.l., 2.VI.2012, 1 specimen, G. Altadonna leg., M. Selis det. (MSC); ibidem, 9.VIII.2013, 1 specimen, G. Altadonna leg., M. Selis det. (GAC); ibidem, 16.VIII.2014, 1 specimen, G. Altadonna leg., M. Selis det. (GAC); ibidem, 19.VIII.2014, 1 specimen, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC); ibidem, 22.VIII.2014, 1 specimen, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC).

DISTRIBUTION. Mediterranean.

REMARKS. Previously recorded for Vulcano, Lipari and Salina by Borsato & Turrisi (2004).

Eumenes coarctatus* ssp. *maroccanus Gusenleitner, 1972

EXAMINED MATERIAL. Vulcano: VII.1993, 1 male, M. Mei leg., W. Borsato det. (WBC).

DISTRIBUTION. South European Maghrebian.

REMARKS. The material examined is quoted in Borsato & Turrisi (2004).

Eumenes mediterraneus* ssp. *mediterraneus Kriechbaumer, 1879

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI.1997, 1 male, 3 females, G.F. Turrisi leg., W. Borsato det. (GFTC) (quoted in Borsato & Turrisi, 2004). Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 2 females, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC).

DISTRIBUTION. Mediterranean.

REMARKS. Recorded for Lipari by Borsato & Turrisi (2004), newly recorded for Vulcano.

Delta unguiculatum (Villers, 1789) (Fig. 13)

EXAMINED MATERIAL. Lipari: Monte Guardia, 2.VI.1997, 1 male, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. South European West Asian.

REMARKS. New for the Aeolian Archipelago.

Rynchium oculatum (Fabricius, 1781)

EXAMINED MATERIAL. Vulcano: crater, VII.2017, 1 male, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Mediterranean South West Asian.

REMARKS. New for the Aeolian Archipelago.

Vespa crabro* ssp. *crabro Linnaeus, 1758

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 9.VIII.2015, 1 male, G. Altadonna leg., wine trap, M. Selis det. (GAC).

DISTRIBUTION. European Asian. This species is widely introduced in the Nearctic and Southern Hemisphere.

REMARKS. New for the Aeolian Archipelago.

***Polistes (Polistes) dominula* (Christ, 1791)**

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 21.VIII.2014, 1 male, G. Altadonna leg., M. Selis det. (GAC); ibidem, 9-22.VIII.2015, 1 male, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC).

DISTRIBUTION. European Maghrebian (introduced to South Africa, Australia and America).

REMARKS. New for the Aeolian Archipelago. The taxonomic concept and distribution of the species belonging to the genus *Polistes* Latreille herein identified follow the recent review of Schmid-Egger et al., (2017).

***Polistes (Polistes) gallicus* (Linnaeus, 1767) (Fig. 14)**

EXAMINED MATERIAL. Panarea, 23.VI.1967, 2 females, Sulfaro leg., M. Selis det. (GFTC). Vulcano, 12.IV.1968, 1 female, G. Marcuzzi leg., M. Selis det. (GFTC); Vulcano: Capo Secco, 16.VIII.2015, 2 females, G. Altadonna leg., M. Selis det. (GAC); Vulcano: Piano, 330 m a.s.l., 19.VIII.2014, 1 specimen, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC); Piano, 9-22.VIII.2015, 9 females, 2 males, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC); ibidem, 12-18.VIII.2016, 5 specimens, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

***Polistes (Polistes) nimpha* (Christ, 1791)**

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 1 female, G. Altadonna leg., yellow pan trap, M. Selis det. (MSC); ibidem, 12-18.VIII.2016, yellow pan trap, 2 specimens, G. Altadonna leg., M. Selis det. (MSC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

***Vespula (Paravespula) germanica* (Fabricius, 1793)**

EXAMINED MATERIAL. Vulcano: Gelso, 30.VIII.2014, 1 specimen, G. Altadonna leg., M. Selis det. (MSC); Vulcano: Piano, 3.III.2019, 1 specimen, G. Altadonna leg., G.F. Turrise det. (GAC). Lipari: Canneto, 21.II.1966, 1 female, M. La Greca leg., G.F. Turrise det. (GFTC).

DISTRIBUTION. Palaearctic (largely introduced and widespread in the Nearctic).

REMARKS. New for the Aeolian Archipelago.

SPHECIDAE

***Sceliphron destillatorium* (Illiger, 1807)**

EXAMINED MATERIAL. Panarea, 18.VI.1967, 1 female, Sulfaro leg., G.F. Turrise det. (GFTC).

DISTRIBUTION. South Palaearctic.

REMARKS. Recorded for Panarea by Turrise & Altadonna (2017).

***Sceliphron spirifex* (Linnaeus, 1758)**

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 6.VII.2012, 1 female, G. Altadonna leg., G.F. Turrise det. (GFTC).

DISTRIBUTION. West Palaearctic.

REMARKS. Recorded for Vulcano by Turrise & Altadonna (2017), already known for other circum-sicilian islands (Ustica and Lampedusa) (Riggio & De Stefani Perez, 1888; Pagliano & Scaramozzino, 1995).

***Ammophila heydeni* Dahlbom, 1845**

EXAMINED MATERIAL. Lipari: Vallone Muria, 14.VII.1995, 1 female, P. Lo Cascio leg., G.F. Turrise det. (PLCC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

***Prionyx subfuscatus* (Dahlbom, 1845) (Fig. 15)**

EXAMINED MATERIAL. Lipari: Timpone Ricotta,

8.X.1996, 1 female, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

Prionyx lividocinctus (A. Costa, 1858)

EXAMINED MATERIAL. Lipari: Contrada San Giorgio, 15.X.1967, 1 male, Cirotti leg., G.F. Turrisi det. (GFTC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

Sphex funerarius Gussakovskij, 1934

EXAMINED MATERIAL. Lipari: Monte Chirica, 26.IX.1996, 1 male, P. Lo Cascio leg., G.F. Turrisi det. (PLCC); Lipari: Madoro, 21.VIII.1996, 1 male, P. Lo Cascio & S. Pasta leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

CRABRONIDAE

Dryudella esterinae Pagliano, 2001 (Fig. 16)

EXAMINED MATERIAL. Lipari: Vallone Muria, 3. VI.1997, 1 male, P. Lo Cascio leg., G.F. Turrisi det. (PLCC).

DISTRIBUTION. South West European.

REMARKS. New for the Aeolian Archipelago and Sicily.

Dryudella tricolor (Van der Linden, 1829)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI. 1997, 1 female, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

Harpactus laevis (Latreille, 1792)

EXAMINED MATERIAL. Lipari: Vallone Muria,

VII.1999, 1 male, P. Lo Cascio leg., Moericke trap, G.F. Turrisi det. (PLCC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

Nysson quadriguttatus Spinola, 1808

EXAMINED MATERIAL. Vulcano: Piano, 9.VI. 20 13, 1 female, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. European.

REMARKS. New for the Aeolian Archipelago and Sicily.

Crossocerus distinguendus (Morawitz, 1866)

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg. et det. (GFTC). Lipari: Pianoconte, 7.VI.1997, 1 male, G.F. Turrisi leg. et det. (GFTC).

DISTRIBUTION. European Maghrebian.

REMARKS. New for the Aeolian Archipelago.

Crossocerus quadrimaculatus (Fabricius, 1793)

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI. 1997, 1 male, G.F. Turrisi leg. et det. (GFTC).

DISTRIBUTION. Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Lestica clypeata (Schreber, 1759) (Fig. 17)

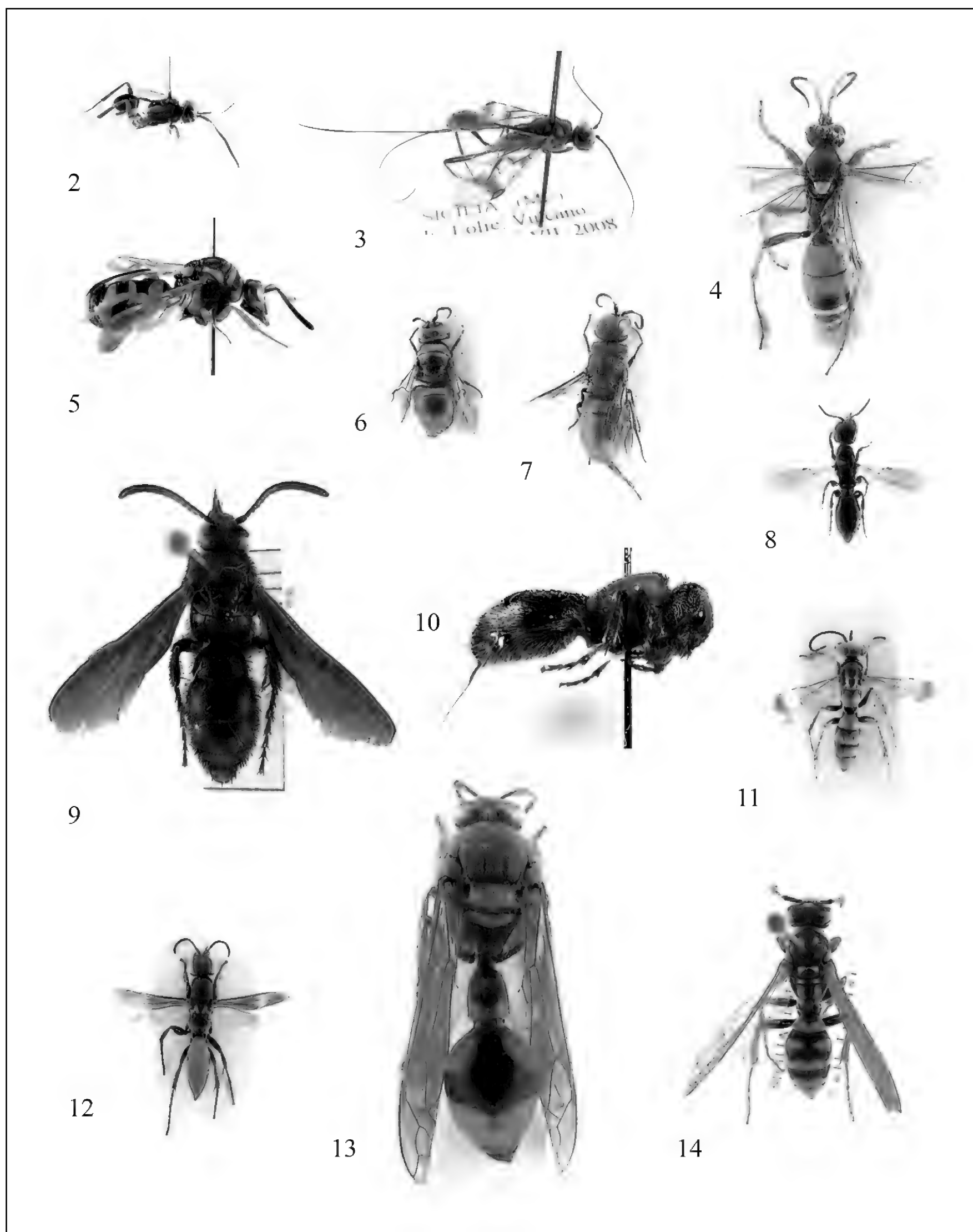
EXAMINED MATERIAL. Lipari: Urnazzo, 2.VI. 1997, 1 male, P. Lo Cascio leg., on *Daucus* sp., G.F. Turrisi det. (PLCC).

DISTRIBUTION. Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Tracheliodes quinquenotatus (Jurine, 1807) (Fig. 18)

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI. 1997, 1 male, G.F. Turrisi leg. et det. (GFTC). Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 2 males, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).



Figures 2–14. Hymenoptera of Aeolian Archipelago (not in scale). Fig. 2: *Zeuxevania splendidula* female (Lipari). Fig. 3: *Pristaulacus lindae* female (Vulcano). Fig. 4: *Eutanyacra picta* female (Vulcano). Fig. 5: *Leucospis gigas* female (Lipari). Fig. 6: *Holopyga fervida* female (Lipari). Fig. 7: *Chrysis cerastes* female (Salina). Fig. 8: *Meria dorsalis* female (Lipari). Fig. 9: *Scolia carbonaria* male (Lipari). Fig. 10: *Ronisia brutia* female (Lipari). Fig. 11: *Pompilus cinereus* female (Vulcano). Fig. 12: *Aporus bicolor* female (Lipari). Fig. 13: *Delta unguiculatum* male (Lipari). Fig. 14: *Polistes gallicus* worker (Lipari).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Tachysphex costae (De Stefani-Perez, 1882)

EXAMINED MATERIAL. Vulcano: Piano, 9.VI.2013, 1 female, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. Southern West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Tachysphex nitidior Beaumont, 1940

EXAMINED MATERIAL. Vulcano: Piano, 9.VI.2013, 1 male, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. Southern West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Miscophus eatoni Saunders, 1903

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 1 female, G. Altadonna leg., yellow pan trap, M. Selis det. (MSC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago and Sicily.

Miscophus lusitanicus Andrade, 1952

EXAMINED MATERIAL. Panarea: Soldata, 230 m a.s.l., 21.VIII.2015, 1 male, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. South European Anatolian.

REMARKS. New for the Aeolian Archipelago; first record for Italy.

Miscophus pretiosus Kohl, 1884

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 1 female, G. Altadonna leg., yellow-pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. South European Anatolian.

REMARKS. New for the Aeolian Archipelago.

Solierella compedita (Piccioli, 1869)

EXAMINED MATERIAL. Lipari: Vallone Muria, VII.1999, 1 male, P. Lo Cascio leg., Moericke trap, G.F. Turrisi det. (PLCC). Panarea: Soldata, 230 m a.s.l., 21.VIII.2015, 2 males, G. Altadonna leg., yellow-pan trap, M. Selis det. (MSC); ibidem, 21.VIII.2015, 2 males, G. Altadonna leg., yellow-pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Pison atrum (Spinola, 1808)

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 female, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Trypoxylon kolazyi Kohl, 1893

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 2 males, G.F. Turrisi leg. and det. (GFTC). Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 1 female, G. Altadonna leg., yellow pan trap, G.F. Turrisi det. (GAC).

DISTRIBUTION. South European Anatolian.

REMARKS. New for the Aeolian Archipelago. Recently recorded for Sicily (Schmid-Egger, 2003; Tomarchio & Turrisi, 2006) and Lampedusa (Pagliano, 2003).

Trypoxylon deceptorium Antropov, 1991

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 1 female, G. Altadonna leg., yellow pan trap, M. Selis det. (MSC).

DISTRIBUTION. European South West Asian.

REMARKS. New for the Aeolian Archipelago. Recently recorded for Sicily by Tomarchio & Turrisi (2006).

Trypoxylon scutatum Chevrier, 1867

EXAMINED MATERIAL. Lipari: Castello environs,

8.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC). Vulcano: Piano, 330 m a.s.l., 9-22.VIII.2015, 3 females, G. Altadonna leg., yellow pan trap, M. Selis det. (GAC); ibidem, 12-18.VIII.2016, 2 specimens, G. Altadonna leg., yellow pan trap, M. Selis det. (MSC).

DISTRIBUTION. European Anatolian.

REMARKS. New for the Aeolian Archipelago.

***Ammoplanus perrisi* Giraud, 1869**

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. European.

REMARKS. New for the Aeolian Archipelago.

***Passaloecus pictus* Ribaut, 1952**

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI.1997, 2 females, G.F. Turrisi leg. and det. (GFTC). Lipari: Castello environs, 8.VI.1997, 7 females, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. South European Anatolian.

REMARKS. New for the Aeolian Archipelago. Recorded for Sicily by Schmid-Egger (2003) and Tomarchio & Turrisi (2006).

***Pemphredon austriaca* (Kohl, 1888)**

EXAMINED MATERIAL. Lipari: Pianoconte, 7.VI.1997, 1 male, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. European.

REMARKS. New for the Aeolian Archipelago.

***Mimesa grandii* Maidl, 1933 (Fig. 19)**

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 female, G.F. Turrisi leg. et det. (GFTC).

DISTRIBUTION. West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Cerceris circularis* ssp. *dacica* Schletterer, 1887**

EXAMINED MATERIAL. Lipari: Castello environs,

8.VI.1997, 1 male, G.F. Turrisi leg. et det., on *Daucus* sp. (GFTC).

DISTRIBUTION. South European.

REMARKS. New for the Aeolian Archipelago and Sicily.

***Philanthus coarctatus* ssp. *siculus* Giordani Soika, 1944 (Fig. 20)**

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 4 males, G.F. Turrisi leg. et det., on *Daucus* sp. (GFTC).

DISTRIBUTION. South Italian.

REMARKS. New for the Aeolian Archipelago.

FORMICIDAE

***Aphaenogaster pallida* (Nylander, 1848)**

EXAMINED MATERIAL. Filicudi: Fossa delle Felci, 1.I.1997, P. Lo Cascio leg., F. Rigato det. (PLCC). Lisca Bianca: 7.IV.1996, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC).

DISTRIBUTION. South East European.

REMARKS. Recorded for Lipari (Kutter, 1927) and Salina (Schär et al., 2020), is newly recorded for Filicudi and the islet Lisca Bianca.

***Aphaenogaster subterranea* (Latreille, 1798)**

EXAMINED MATERIAL. Strombolicchio: 29.VI.1998, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. Mediterranean European.

REMARKS. Recorded for all the main islands except Vulcano (Schär et al., 2020), is newly recorded for the islet Strombolicchio.

***Camponotus lateralis* (Olivier, 1791)**

EXAMINED MATERIAL. Vulcano: Monte Lentia, 4.VI.1997, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. Mediterranean Turanian.

REMARKS. Recorded for Lipari (Kutter, 1927),

Vulcano (Baroni Urbani, 1964), Salina, Stromboli, Filicudi and Panarea (Schär et al., 2020).

Camponotus micans (Nylander, 1856)

EXAMINED MATERIAL. Lipari: Timpone Ricotta, 8.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded for Lipari (Kutter, 1927), Salina, Vulcano and Filicudi (Schär et al., 2020).

Camponotus nylanderi Emery, 1921

EXAMINED MATERIAL. Lipari: Timpone Ricotta, 8.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC). Filicudi: Fossa delle Felci, 1.I.1997, P. Lo Cascio leg., F. Rigato det. (PLCC). Alicudi: Pianicello, 2.IV.1997, P. Lo Cascio & G. Serra leg., F. Rigato det. (PLCC). Strombolicchio: 6.VIII.1994, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC); 29.VI.1998, P. Lo Cascio leg., F. Rigato det. (PLCC). Scoglio Faraglione: 5.VIII.1994, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC).

DISTRIBUTION. South Italian.

REMARKS. Recorded for Lipari (Kutter, 1927), the islet Strombolicchio (Lo Cascio, 2004), Salina, Vulcano, Stromboli, Filicudi and Panarea (Schär et al., 2020), is newly recorded for Alicudi and the islet Scoglio Faraglione.

Crematogaster scutellaris (Olivier, 1791)

EXAMINED MATERIAL. Lipari: Vallone Muria, 14.X.1998, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. Mediterranean.

REMARKS. Recorded for Lipari (Kutter, 1927), Salina (Monastero & Genduso, 1964b), Vulcano, Stromboli, Filicudi and Panarea (Schär et al., 2020).

Lepisiota nigra (Dalla Torre, 1893)

EXAMINED MATERIAL. Strombolicchio: 25.VI.1998, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. Mediterranean Turanian.

REMARKS. Recorded for Lipari, Salina, Vulcano

and Panarea (Schär et al., 2020), is newly recorded for the islet Strombolicchio.

Messor capitatus (Latreille, 1798)

EXAMINED MATERIAL. Lipari: Timpone Ricotta, 8.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC); Fuaro, 9.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded for Lipari (Kutter, 1927; Baccetti, 1967; Schär et al., 2020).

Messor minor* ssp. *calabricus Santschi, 1927

EXAMINED MATERIAL. Lisca Bianca: 7.IV.1996, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC).

DISTRIBUTION. Southern Italian.

REMARKS. Recorded for Lisca Bianca (Lo Cascio & Navarra, 2003).

Messor structor (Latreille, 1798)

EXAMINED MATERIAL. Lipari: Fuaro, 9.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. South East European.

REMARKS. Already recorded for Lipari (Kutter, 1927).

Pheidole pallidula (Nylander, 1848)

EXAMINED MATERIAL. Stromboli: path to the crater, 400 m a.s.l., 24.X.1996, P. Lo Cascio leg., F. Rigato det. (PLCC).

DISTRIBUTION. West Mediterranean.

REMARKS. Recorded for Lipari (Kutter, 1927), Filicudi (Seifert, 2016), Salina, Vulcano, Stromboli and Panarea (Schär et al., 2020).

Plagiolepis pallescens Lomnicki, 1925

EXAMINED MATERIAL. Strombolicchio: 6.IV.1996, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC).

DISTRIBUTION. West Palaearctic.

REMARKS. Recorded for all the main islands except Filicudi (Schär et al., 2020), is newly recorded for the islet Strombolicchio.

Ponera coarctata (Latreille, 1802)

EXAMINED MATERIAL. Alicudi: Pianicello, 2.IV.1997, P. Lo Cascio & G. Serra leg., F. Rigato det. (PLCC).

DISTRIBUTION. South European.

REMARKS. Recorded for Alicudi (Lo Cascio et al., 2006), Lipari and Salina (Schär et al., 2020).

Tetramorium punctatum Santschi, 1927

EXAMINED MATERIAL. Scoglio Faraglione: 6.VIII.1994, P. Lo Cascio & V. Pancioli leg., F. Rigato det. (PLCC).

DISTRIBUTION. East Mediterranean.

REMARKS. Recorded for Lipari (Kutter, 1927 as *T. semilaeve*; Santschi, 1927 as *T. semilaeve* var. *lipareum* nov.; Sanetra et al. 1999), Salina, Vulcano, Stromboli, Filicudi and Panarea (Schär et al., 2020), is newly recorded for the islet Scoglio Faraglione.

COLLETIDAE

Colletes nigricans Gistel, 1857

MATERIAL EXAMINED. Salina, Monte dei Porri, 20.IX.1966, 2 females, Arcidiacono leg., V. Nobile det. (VNC).

DISTRIBUTION. West Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Hylaeus (Paraprosopis) clypearis (Schenck, 1853)

EXAMINED MATERIAL. Panarea: 23.VI.1967, 1 female, Sulfaro leg., V. Nobile det. (VNC).

DISTRIBUTION. South West Palaearctic (introduced in Chile).

REMARKS. New for the Aeolian Archipelago.

Hylaeus (Dentigera) imparilis Förster, 1871

EXAMINED MATERIAL. Lipari: Chiesa Vecchia, 7.VII.1999, 1 female, G.F. Turrise leg., V. Nobile det., on cultivated *Petroselinum* sp. (GFTC).

DISTRIBUTION. South West Palaearctic (introduced in Chile).

REMARKS. New for the Aeolian Archipelago.

Hylaeus (Spatulariella) punctatus (Brullé, 1832)

EXAMINED MATERIAL. Salina: Monte dei Porri, 20.IX.1966, 1 female, Arcidiacono leg., V. Nobile det. (VNC).

DISTRIBUTION. South West Palaearctic (introduced in Chile).

REMARKS. New for the Aeolian Archipelago.

ANDRENIDAE

Andrena (Charitandrena) hattorfiana ssp. ***dimidiata*** Brullé, 1832

EXAMINED MATERIAL. Vulcano: 29.V-4.VI.2010, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central South Anatolian European. The nominate subspecies has a West European Asian distribution.

REMARKS. New for the Aeolian Archipelago.

Andrena (Euandrena) ruficrus Nylander, 1848

EXAMINED MATERIAL. Lipari: Acquacalda, 29.IV.1966, 1 female, I. Marcellino leg., V. Nobile det. (VNC).

DISTRIBUTION. European West Asian.

REMARKS. New for the Aeolian Archipelago.

Andrena (Melandrena) morio ssp. ***morio*** Brullé, 1832

EXAMINED MATERIAL. Vulcano: 26.IV-4.V.2009, 2 females, M. Mei leg., V. Nobile det. (VNC); Panarea: Drauto, 20 m a.s.l., 21.VIII.2015, G. Altadonna leg., 1 female, G.F. Turrise det. (GAC).

DISTRIBUTION. South East European West Asian.

REMARKS. New for the Aeolian Archipelago.

Andrena (Melandrena) nigroaenea ssp. *nigroaenea* (Kirby, 1802)

EXAMINED MATERIAL. Filicudi, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

Andrena (Melandrena) nitida ssp. *nitida* (Müller, 1776)

EXAMINED MATERIAL. Vulcano: Piano, 14. III.2000, 1 female, P. Lo Cascio & S. Pasta leg., on flowers of *Cytisus aeolicus* (PLCC).

DISTRIBUTION. European.

REMARKS. New for the Aeolian Archipelago.

Andrena (Plastandrena) pilipes Fabricius, 1781

EXAMINED MATERIAL. Vulcano, 29.V.4.VI.2010, 2 females, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Andrena (Scitandrena) scita Eversmann, 1852

EXAMINED MATERIAL. Vulcano, 29.V-4.VI.2010, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South East European South West Asian.

REMARKS. New for the Aeolian Archipelago.

Andrena (Taeniandrena) wilkella (Kirby, 1802)

EXAMINED MATERIAL. Vulcano, 25.IV-4.V.2009, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

HALICTIDAE

Pseudapis bispinosa (Brullé, 1832)

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 6 males, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

Ceulalictus variegatus (Olivier, 1789)

EXAMINED MATERIAL. Vulcano: 24.VII.1963, 2 males, 1 female, V. Nobile leg. et det. (VNC). Vulcano: 3-17.VII.1993, 1 male, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

Nomioides facilis (Smith, 1853)

EXAMINED MATERIAL. Lipari: Urnazzo, 2.VI.1997, 1 female, P. Lo Cascio leg., on Asteraceae, V. Nobile det. (PLCC).

DISTRIBUTION. Mediterranean Asian.

REMARKS. New for the Aeolian Archipelago.

Nomioides minutissimus (Rossi, 1790)

EXAMINED MATERIAL. Vulcano: Piano, 9-22.VIII.2015, 1 female, G. Altadonna leg., V. Nobile det. (yellow pan-trap) (GAC).

DISTRIBUTION. Mediterranean South West Asian.

REMARKS. New for the Aeolian Archipelago.

Halictus (Halictus) quadricinctus (Fabricius, 1776)

EXAMINED MATERIAL. Panarea: 12.VI.1967, 1 female, V. Nobile leg. et det. (VNC). Vulcano: 28.VI-18.VI.2008, 2 males, M. Mei leg., V. Nobile det. (VNC); 29.V-4.VI.2010, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Halictus (Hexataenites) fulvipes (Klug, 1817)

EXAMINED MATERIAL. Lipari: Monte Chirica,

26.IX.1996, 1 male, P. Lo Cascio leg., V. Nobile det. (PLCC). Panarea: 18.VI.1967, 1 female, Sulfaro leg., V. Nobile det. (VNC). Vulcano: 24.VII.1963, 1 female, V. Nobile leg. et det. (VNC); 10.VII.1993, 2 males, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Mediterranean Asian (introduced in Mexico).

REMARKS. New for the Aeolian Archipelago.

Halictus (Hexataenites) scabiosae (Rossi, 1790) (Fig. 21)

EXAMINED MATERIAL. Lipari: Vallone Muria, VII.1999, 1 female, P. Lo Cascio leg., V. Nobile det. (Moericke trap) (PLCC).

DISTRIBUTION. South West Palaearctic (extended to South Africa).

REMARKS. New for the Aeolian Archipelago.

Halictus (Monilapis) compressus Walckenaer, 1802

EXAMINED MATERIAL. Lipari: Quattropani, 6. VI.1997, 1 male, 2 females, on flowers of *Rubus* sp., G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. South European Central Asian (excluding Iberian Peninsula).

REMARKS. New for the Aeolian Archipelago.

Halictus (Seladonia) gemmeus Dours, 1872

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Halictus (Seladonia) smaragdulus Vachal, 1895

EXAMINED MATERIAL. Vulcano: 24.VII.1963, 2 females, V. Nobile leg. and det. (VNC).

DISTRIBUTION. South West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Halictus (Tyththalictus) asperulus Perez, 1895

EXAMINED MATERIAL. Panarea: 23.VI.1967, 1

male, Sulfaro leg., V. Nobile det. (VNC). Vulcano, 15.VII.1993, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Mediterranean South West Asian.

REMARKS. New for the Aeolian Archipelago.

Halictus (Tyththalictus) maculatus Smith, 1848

EXAMINED MATERIAL. Panarea: 23.VI.1967, 1 male, Sulfaro leg., V. Nobile det. (VNC).

DISTRIBUTION. South European Turanian.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Dialictus) nitidulum (Fabricius, 1804)

EXAMINED MATERIAL. Lipari: Monte Sant'Angelo, 500 m a.s.l., 21.II.1966, 2 females, M. La Greca leg., V. Nobile det. (VNC).

DISTRIBUTION. South European Central Asian.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Dialictus) planulum (Perez, 1903)

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1 male, G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. North Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Dialictus) semilucens (Alfken, 1914)

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. Central South European Central Asian.

REMARKS. New for the Aeolian Archipelago and Sicily.

Lasioglossum (Sphecodogastra) immunitum ssp. *sillatum* (Warncke, 1981)

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Sicilian Sardinian South Italian. The nominate subspecies has a Mediterranean Iranian distribution (discontinuous in the South East Mediterranean).

REMARKS. Described from Catania (holotype) and Lipari: Mount Guardia (paratypes) (Warncke, 1981). The holotype was collected on flowers of *Centaurea* (Asteraceae).

Lasioglossum (Sphecodogastra) malachurum
(Kirby, 1802)

EXAMINED MATERIAL. Lipari: Mount Sant'Angelo, m 500, 21.II.1966, 1 female, M. La Greca leg. (DSCC); Pianoconte, 7.VI.1997, 1 male, G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. Central South West Palaearctic Macaronesian.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Sphecodogastra) opacum Perez, 1895

EXAMINED MATERIAL. Lipari: Quattropiani-Acquacalda, 22.II.1966, 1 female, M. La Greca leg., V. Nobile det. (DSCC); Acquacalda, 29.VI.1966, 1 female, I. Marcellino leg., V. Nobile det. (DSCC); Urnazzo, 2.VI.1997, 1 male, P. Lo Cascio leg., on Asteraceae, V. Nobile det. (PLCC); Quattropiani, 6.VI.1997, 1 male, G.F. Turrisi leg., V. Nobile det. (GFTC); Pianoconte, 7.VI.1997, 1 female, G.F. Turrisi leg., V. Nobile det. (GFTC). Vulcano: 10.VII.1993, 3 males, 2 females, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Mediterranean Iranian.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Sphecodogastra) nigripes (Lepelletier, 1841)

EXAMINED MATERIAL. Lipari: Mendolita, 30.VI.1967, 1 female, Cirotti leg., V. Nobile det. (DSCC).

DISTRIBUTION. Central South West Mediterranean Macaronesian.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Sphecodogastra) pauxillum
(Schenck, 1853)

EXAMINED MATERIAL. Panarea: 12.VI.1967, 2

males, V. Nobile leg. (VNC); 23.VI.1967, 1 males, Sulfaro leg., V. Nobile det. (DSCC).

DISTRIBUTION. Central South West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Sphecodogastra) subhirtum
(Lepelletier, 1841)

EXAMINED MATERIAL. Lipari: Urnazzo, 2. VI. 1997, 1 male, on flowers of *Daucus* sp. (Apiaceae), P. Lo Cascio leg., V. Nobile det. (LPC).

DISTRIBUTION. Central South West Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Lasioglossum) albocinctum
(Lucas, 1849)

EXAMINED MATERIAL. Vulcano: 10.VII.1993, 3 males, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. European Mediterranean (discontinuous in North East Africa).

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Lasioglossum) bimaculatum
(Dours, 1872)

EXAMINED MATERIAL. Lipari: Pianoconte, 24.V.1967, 1 female, V. Nobile leg. and det. (VNC). Vulcano: 3-17.VII.1993, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. West Mediterranean.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Lasioglossum) costulatum
(Kriechbaumer, 1873)

EXAMINED MATERIAL. Lipari: Pianoconte, 24.V.1967, 1 female, V. Nobile leg. and det. (VNC).

DISTRIBUTION. Palaearctic.

REMARKS. New for the Aeolian Archipelago.

Lasioglossum (Lasioglossum) leucozonium
ssp. *cedri* Ebmer, 1976

EXAMINED MATERIAL. Lipari: Acquacalda, 29. IV.1966, 1 female, I. Marcellino leg., V. Nobile det. (DSCC).

DISTRIBUTION. South West Mediterranean. The species is European Central Asian.

REMARKS. New for the Aeolian Archipelago.

Sphecodes albilabris (Fabricius, 1793) (Fig. 22)

EXAMINED MATERIAL. Lipari: Vallone Muria, 3. VI.1997, 1 female, P. Lo Cascio leg., V. Nobile det. (PLCC).

DISTRIBUTION. European Central Asian.

REMARKS. New for the Aeolian Archipelago.

Sphecodes gibbus (Linnaeus, 1758)

EXAMINED MATERIAL. Vulcano: 25.IV-4.V.2009, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. European Asian.

REMARKS. New for the Aeolian Archipelago.

Sphecodes monilicornis ssp. *quadratus* Meyer, 1919

EXAMINED MATERIAL. Vulcano: 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South European. The species is Palearctic.

REMARKS. New for the Aeolian Archipelago.

Sphecodes spinulosus Hagens, 1875

EXAMINED MATERIAL. Vulcano: 25.IV-4.V.2009, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. European West Asian.

REMARKS. New for the Aeolian Archipelago.

MEGACHILIDAE

Heriades (Heriades) truncorum (Linnaeus, 1758)

EXAMINED MATERIAL. Vulcano: 25.IV-4.V.2009, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. West Central Palearctic.

REMARKS. New for the Aeolian Archipelago.

Hoplitis (Hoplitis) adunca ssp. *adunca* (Panzer, 1798)

EXAMINED MATERIAL. Vulcano: 25.IV-4.V.2009, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central South European Central Asian. The other subspecies, *Hoplitis (Hoplitis) adunca* ssp. *contraria* Tkalcu, 1974 has an Iberian Maghrebian distribution.

REMARKS. New for the Aeolian Archipelago.

Hoplitis (Hoplitis) lepeletieri (Panzer, 1798)

EXAMINED MATERIAL. Vulcano, 25.IV-4.V.2009, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central South West European.

REMARKS. New for the Aeolian Archipelago.

Osmia (Helicosmia) latreillei ssp. *iberoafricana* Peters, 1975

EXAMINED MATERIAL. Filicudi, 14.VII.1993, 1 female, M. Mei leg., V. Nobile det. (VNC); Vulcano, 29.V-4.VI.2010, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South Mediterranean Macaronesian. The nominate subspecies is South European, excluding Iberian Peninsula.

REMARKS. New for the Aeolian Archipelago.

Osmia (Pyrosmia) submicans ssp. *hebraea* Benoist, 1934

EXAMINED MATERIAL. Vulcano, 29.V-4.VI.2010, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. South Mediterranean. The nominate subspecies is Central South European.

REMARKS. New for the Aeolian Archipelago.

Rhodanthidium septemdentatum (Latreille, 1809)

EXAMINED MATERIAL. Lipari: Quattropani, 6.

VI.1997, 1 male, G.F. Turrisi leg., V. Nobile det. (GFTC); Pianoconte, 7.VI.1997, 1 female, G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. North Mediterranean.

REMARKS. New for the Aeolian Archipelago.

***Stelis phaeoptera* ssp. *murina* Perez, 1884**

EXAMINED MATERIAL. Lipari: VI.2000, 1 male, 5 females, Sinacori leg., reared from *Arundo* stems together with the host *Osmia* (*Chalcosmia*) sp., V. Nobile det. (VNC).

DISTRIBUTION. South Mediterranean Iranian Macaronesian. The nominate subspecies is Central North European Central Asian.

REMARKS. New for the Aeolian Archipelago.

***Dioxys cincta* (Jurine, 1807)**

EXAMINED MATERIAL. Lipari: 14.IV.1968, 1 female, G. Marcuzzi leg., V. Nobile det. (DSCC).

DISTRIBUTION. Central European Mediterranean African.

REMARKS. Recorded for Lipari by Nobile & Turrisi (1996).

***Megachile (Chalicodoma) parietina* (Geoffroy, 1785)**

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI. 1997, 1 female, G.F. Turrisi leg., V. Nobile det. (GFTC). Panarea: 23.VI.1967, 1 female, Sulfaro leg., V. Nobile det. (DSCC).

DISTRIBUTION. Central South Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Megachile (Chalicodoma) sicula* Rossi, 1792**

EXAMINED MATERIAL. Lipari: Vallone Ponte, 22. II.1967, 1 male, S. Bruno leg., V. Nobile det. (DSCC).

DISTRIBUTION. South Palaearctic Macaronesian.

REMARKS. New for the Aeolian Archipelago.

***Megachile (Eutricharaea) apicalis* Spinola, 1808**

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1 female, G.F. Turrisi leg., V. Nobile det. (GFTC).

DISTRIBUTION. Central South European Maghreb-ian Central Asian (extended to North America).

REMARKS. Recorded for Vulcano by Comba & Comba (2005).

***Megachile (Eutricharaea) pilidens* Alfken, 1923**

EXAMINED MATERIAL. Vulcano: 28.VI-18. VII. 2008, 1 male, 1 female, M. Mei leg., V. Nobile det. (VNC). Vulcano: Piano, 330 m, 21.VIII.2014, 1 specimen, G. Altadonna leg., V. Nobile det. (PNC).

DISTRIBUTION. Mediterranean Central European Iranian.

REMARKS. Recorded for Vulcano by Comba & Comba (2005).

APIDAE

***Xylocopa violacea* (Linnaeus, 1758)**

EXAMINED MATERIAL. Lipari: Pianoconte, 7. VI.1997, 1female, G.F. Turrisi leg. and det. (GFTC). Vulcano: Piano, 21.VIII.2014, 1female, G. Altadonna leg., G.F. Turrisi det. (GAC). Vulcano: Gelso, 12.VIII.2016, 1female, G. Altadonna leg., G.F. Turrisi det. (GAC).

DISTRIBUTION. Palaearctic (recorded also for Mexico).

REMARKS. Recorded for Lipari, Filicudi, Panarea, and Vulcano by Pagliano & Nobile (1993), Vicidomini (2003), and Vicidomini et al., (2005); for Stromboli by Comba & Comba (2005). The similar *X. valga* Gerstaecker, 1872 is recorded for Stromboli by Pagliano & Nobile (1993), Vicidomini (2003), and Vicidomini et al., (2005).

***Ceratina cucurbitina* (Rossi, 1792)**

EXAMINED MATERIAL. Lipari: Urnazzo, 2.VI. 1997, 1 female, P. Lo Cascio leg., on *Daucus* sp.,

V. Nobile det. (PLCC); Chiesa Vecchia, 7.VI.1999, on cultivated *Petroselinum* sp. (Apiaceae), G.F. Turrisi leg., V. Nobile det. (GFTC). Vulcano: Piano, 9-22.VIII.2015, 1 male (yellow-pan trap), G. Altadonna leg., V. Nobile det. (GAC). Alicudi: Pianicello, 2.IV.1997, 1 female, Lo Cascio & Serra leg., V. Nobile det. (PLCC).

DISTRIBUTION. Central South West Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Nomada fulvicornis* Fabricius, 1793**

EXAMINED MATERIAL. Vulcano: 25.IV-4.V.2009, 2 female, M. Mei leg., V. Nobile det. (VNC). Vulcano, 29.V-4.VI.2010, 1 male, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central South Palaearctic.

REMARKS. New to Aeolian archipelago.

***Epeolus julliani* Perez, 1884**

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 female, M. Mei leg. and det. (VNC).

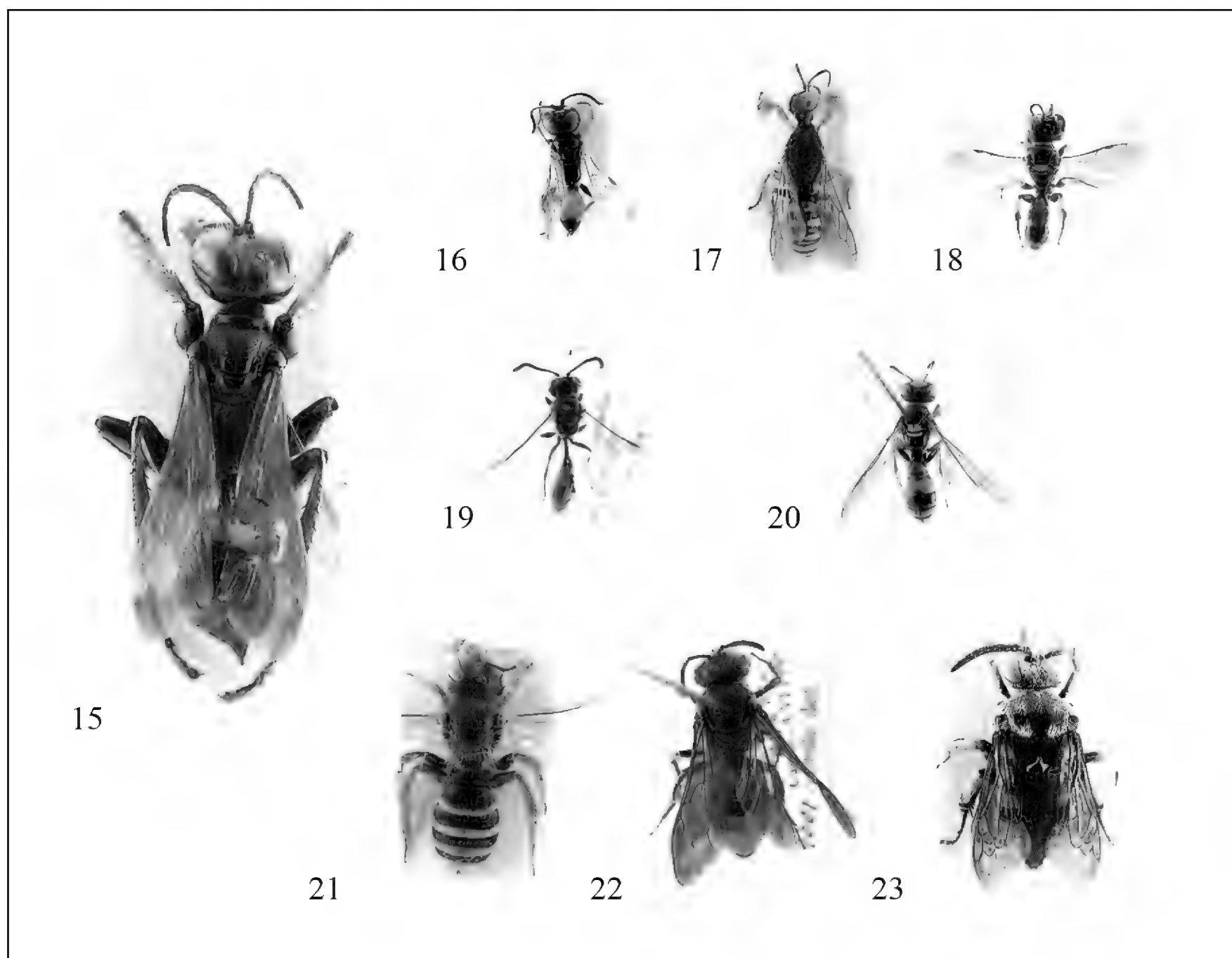
DISTRIBUTION. South European Anatolian.

REMARKS. New for the Aeolian Archipelago.

***Pasites maculatus* Jurine, 1807**

EXAMINED MATERIAL. Vulcano: 3-17.VII.1993, 1 male, 2 females, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central West Palaearctic.



Figures 15–23. Hymenoptera of Aeolian Archipelago (not in scale). Fig. 15: *Prionyx subfuscatus* female (Lipari). Fig. 16: *Dryudella esterinae* male (Lipari). Fig. 17: *Lestica clypeata* male (Lipari). Fig. 18: *Tracheliodes quinquenotatus* female (Lipari). Fig. 19: *Mimesa grandii* female (Lipari). Fig. 20: *Philanthus coarctatus siculus* male (Lipari). Fig. 21: *Halictus scabiosae* female (Lipari). Fig. 22: *Sphecodes albilabris* female (Lipari). Fig. 23: *Thyreus ramosus* male (Basiluzzo).

REMARKS. New for the Aeolian Archipelago.

***Eucera (Eucera) nigrescens* Perez, 1879**

EXAMINED MATERIAL. Alicudi: 5.VII.1993, 1 male, 1 female, M. Mei leg., V. Nobile det. (VNC). Vulcano, 15.VII.1993, 1 female, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central South European Iranian.

REMARKS. New for the Aeolian Archipelago.

***Tetraloniella dentata* (Germar, 1839)**

EXAMINED MATERIAL. Vulcano: 29.V-4.VI.2010, 1 male, M. Mei leg., V. Nobile det. (VNC).

DISTRIBUTION. Central Southern Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Amegilla albigena* (Lepelletier, 1841)**

EXAMINED MATERIAL. Vulcano: 24.VII.1963, 1 female, V. Nobile leg. and det. (VNC).

DISTRIBUTION. Mediterranean Central North East African.

REMARKS. New for the Aeolian Archipelago.

***Amegilla garrula* (Rossi, 1790)**

EXAMINED MATERIAL. Lipari: Castello environs, 8.VI.1997, 1 male, G.F. Turrisi leg., V. Nobile det. (GFTC). Salina: Monte Dei Porri, 20.IX.1966, 1 female, S. Arcidiacono leg., V. Nobile det. (VNC).

DISTRIBUTION. South European Iranian.

REMARKS. New for the Aeolian Archipelago.

***Thyreus ramosus* (Lepelletier, 1841) (Fig. 23)**

EXAMINED MATERIAL. Basiluzzo: 20.VIII.1996, 1 male, P. Lo Cascio leg., V. Nobile det. (PLCC).

DISTRIBUTION. South Palaearctic Macaronesian.

REMARKS. New for the Aeolian Archipelago.

***Anthophora (Lophanthophora) dispar* Lepelletier, 1841**

EXAMINED MATERIAL. Vulcano: Piano, 14.

III.2000, 2 females, 1 male, P. Lo Cascio & S. Pasta leg., on *Cytisus aeolicus* Guss. ex Lindl., V. Nobile det. (PLCC).

DISTRIBUTION. Mediterranean.

REMARKS. Recorded for Vulcano by Lo Cascio (2004) (sub *Lophanthophora* *dispar*) and for Alicudi by Comba & Comba (2005).

***Anthophora (Anthophora) plumipes* ssp. *niger* (Friese, 1896)**

EXAMINED MATERIAL. Vulcano: Piano, 330 m a.s.l., 2.VI.2012, 1 specimen, G. Altadonna leg., V. Nobile det. (PNC).

DISTRIBUTION. Palaearctic.

REMARKS. New for the Aeolian Archipelago.

***Bombus (Bombus) terrestris* (Linnaeus, 1758)**

EXAMINED MATERIAL. Vulcano: Piano, 14.III.2000, 1 worker, P. Lo Cascio & S. Pasta leg., on *Cytisus aeolicus* Guss. ex Lindl., V. Nobile det. (PLCC).

DISTRIBUTION. Palaearctic.

REMARKS. Recorded for Vulcano by Lo Cascio (2004).

***Apis mellifera* (Linnaeus, 1758)**

EXAMINED MATERIAL. Lipari: Canale, 30.VI.1967, 1 worker, Allegrina leg., V. Nobile det. (VNC). Lipari: Pianoconte, 7.VI.1997, 1 worker, G.F. Turrisi leg. and det. (GFTC).

DISTRIBUTION. Cosmopolitan.

REMARKS. Recorded for the Aeolian Archipelago by Bouga et al. (2011), Tenore et al. (2012), Muñoz et al. (2014).

DISCUSSION AND CONCLUSIONS

Data from literature (see Introduction) recorded 98 species (including one doubtful record among Formicidae) for the archipelago; 20 of them are confirmed by the present research, and 120 are added as new records. As the whole, 218 species of Hymenoptera belonging to 24 families are currently

known for the Aeolian Islands (Table 1). Among them, *Dryudella esterinae*, *Nysson quadriguttatus*, *Miscophus aetoni*, *Miscophus lusitanicus*, *Cerceris circularis* ssp. *dacica* and *Lasioglossum* (*Dialictus*) *semilucens* are recorded for the first time for Sicily, and *Miscophus lusitanicus* resulted also new for Italy.

Despite this remarkable increase, the hymenopteran fauna of these islands should be considered largely underestimated, especially for many groups of *Terebrantia*, also including those so called “micro Hymenoptera”. No sawflies (“*Symphyla*”) have yet been recorded for the Aeolian Archipelago, but it could be due to the lack of collecting efforts, as suggested by the relatively high diversity and endemism richness that characterizes this group in Sicily, where 139 species were so far recorded (Pesarini & Turrisi, 2001; Turrisi, 2011; Liston et al., 2013); for instance, it is likely that at least some representatives of the most speciose family Tenthredinidae should be occurring also in the Aeolian Archipelago.

On the contrary, these islands harbour a relatively high diversity of Formicidae, with 49 species, and Apoidea, with 68 species belonging to 5 families, and especially Halictidae that include 29 species.

Although the available data are not sufficient to perform an exhaustive biogeographical analysis, taking into account the distributional patterns only, most of the recorded species have a wide European-Mediterranean distribution, and even in the Palaearctic region; moreover, the Mediterranean chorotypes seem to be well represented within the Aeolian fauna.

The Hymenoptera represent one of the four mega-diverse insect orders, and they play a fundamental role in virtually all terrestrial ecosystems as parasitoids, predators, and pollinators, being of substantial economic importance. As the faunal knowledge is likely far to be complete, data concerning population sizes and trends, distribution and conservation of Hymenoptera in the study islands are very limited and essentially based on personal observations carried out by the authors during the field-work.

Anthropogenic disturbance is not strong, but it increases during summer due to the massive occurrence of tourism. This factor, together with urban sprawl and infrastructural developments, may affect structure and dynamics of local ecosystems, as well as the fire, that recently involved large areas of the main islands (f.i., Lipari and Vulcano). The islands have also a long-term history of agricultural ex-

ploitation, that was characterized by a phase of recession and general abandonment between the late 19th and the second half of 20th century. Currently agriculture, and especially viticulture, are gradually spreading again in some islands (Lipari, Salina, Vulcano), but generally moving toward organic practices and avoiding the use of pesticides. On the other hand, the small surface and the rough morphology of the islands hinder strong agricultural changes such as mechanization.

Especially bee populations and species are sensitive to environmental changes, as observed for continental Europe where this problem, together with stress from parasites, pesticides and flower pauperization, has caused honey bee colony losses and declines of wild pollinators (Goulson et al., 2015). However, some of the study islands (Lipari, Vulcano, Filicudi and Alicudi) are now exclusively inhabited by the Sicilian subspecies of honey bee (*Apis mellifera* ssp. *siciliana* Dalla Torre, 1896), that is bred in traditional manner and not exposed to the risk of genetic pollution, as since 1990s the Municipality of Lipari has promulgated an ordinance prohibiting the introduction of other bee races. In this perspective, the islands may be considered as “refuges” for threatened hymenopteran that in other areas (such as Sicily) suffer all the adverse factors above-mentioned, including the modernization of agricultural practices.

More detailed faunal knowledge, together with the extension of the researches to the local population trends and a monitoring programme, are however needed in order to recognize and prevent any negative change that could affect the Aeolian hymenopteran fauna, and consequently its role in agriculture and maintenance of plant diversity. In fact, trends in the decline of Hymenoptera, as with other invertebrates, could be underestimated because of insufficient data both on the number of species, and on the size of local populations. It is not excluded that even among invertebrates, usually considered more “resistant” to the so-called sixth mass extinction (see Leakey & Lewin, 2015 and Kolbert, 2016), some species may disappear even before to be discovered. The development of investigations for a better understanding of the population trends, as well as improvements to the taxonomy and the ecology of the Hymenoptera, are critical for an effective conservation and management of this important faunal component, also for wider benefits associated with pollination network of the ecosystem.

Taxa	Lipari	Salina	Vulcano	Stromboli	Filicudi	Alicudi	Panarea	Islets
EVANIIDAE								
<i>Zeuxevania splendidula</i> (Costa, 1884)	+							
AULACIDAE								
<i>Pristaulacus galitae</i> (Gribodo, 1879)			+					
<i>Pristaulacus lindae</i> Turrisi, 2000			+					
GASTERUPTIIDAE								
<i>Gasteruption assectator</i> (Linnaeus, 1758)	+							
<i>Gasteruption erythrostomum</i> (Dahlbom, 1831)	+							
<i>Gasteruption jaculator</i> (Linnaeus, 1758)	+							
ICHNEUMONIDAE								
<i>Eutanyaera picta</i> (Schrank, 1776)			+					
<i>Clistopyga incitator</i> (Fabricius, 1793)			○					
<i>Zaglyptus multicolor</i> (Gravenhorst, 1829)			○					
EURYTOMIDAE								
<i>Eurytoma martellii</i> Domenichini, 1960		○						
PTEROMALIDAE								
<i>Cyrtoptyx latipes</i> (Rondani, 1874)		○						
<i>Scutellista cyanea</i> Motschulsky, 1859			○					
EUPELMIDAE								
<i>Eupelmus urozonus</i> Dalman, 1820		○						
EULOPHIDAE								
<i>Psigalio mediterraneus</i> Ferrière & Delucchi, 1957		○						
LEUCOSPIDAE								
<i>Leucospis gigas</i> Fabricius, 1793	+			○				
CHRYSIDIDAE								
<i>Hedychridium</i> cf. <i>mediocrum</i> Linsenmaier, 1987		+						
<i>Hedychrum</i> cf. <i>micans europaeum</i> Linsenmaier, 1959		+						
<i>Holopyga fervida</i> (Fabricius, 1781)	+		+	+		+	+	
<i>Pseudomahus auratus</i> (Linnaeus, 1758)	●							
<i>Chrysis</i> cf. <i>auriceps</i> Mader, 1936							+	
<i>Chrysis cerastes</i> Abeille De Perrin, 1877		+						
<i>Chrysis ignita ignita</i> Linnaeus, 1761			○					
<i>Chrysis scutellaris</i> Fabricius, 1794					+			
<i>Pseudochrysis neglecta</i> (Shuckard, 1837)			+					
DRYINIDAE								
<i>Gonatopus lunatus</i> Klug, 1810			○					
TIPHIIDAE								
<i>Tiphia lepeletieri</i> Berland, 1925	+							
<i>Meria tripunctata</i> (Rossi, 1790)	●		+					
<i>Meria dorsalis</i> (Fabricius, 1804)	●		+					

SCOLIIDAE								
<i>Megascolia bidens</i> (Linnaeus, 1767)	○		●					
<i>Megascolia maculata</i> (Drury, 1773)	●	○	●					
<i>Scolia hirta</i> (Schrank, 1781)	+							
<i>Scolia carbonaria</i> (Linnaeus, 1767)	+							
<i>Scolia sexmaculata</i> (Müller, 1766)	○		○					
<i>Colpa sexmaculata</i> (Fabricius, 1781)	○		+	○				
<i>Dasyscolia ciliata</i> (Fabricius, 1787)			+					
MUTILLIDAE								
<i>Bidecoloratilla leopoldina</i> (Invrea, 1955)	○	○	○					
<i>Myrmilla calva</i> (Villiers, 1789)	○		○					
<i>Ronisia brutia brutia</i> (Petagna, 1787)	○	○	○		○		○	
<i>Ronisia ghilianii</i> (Spinola, 1843)	○						○	
<i>Tropidotilla litoralis</i> (Petagna, 1787)	○		○					
<i>Nemka viduata viduata</i> (Pallas, 1773)	○		○	○				
<i>Physetopoda pusilla</i> (Klug, 1835)	○							
<i>Smicromyrme ausonia</i> Invrea, 1950	○							
<i>Smicromyrme partita</i> (Klug, 1835)	○							
<i>Smicromyrme ruficollis ruficollis</i> (Fabricius, 1793)	○		○	○				
<i>Smicromyrme sulcisia</i> Invrea, 1955	○		○					
<i>Smicromyrme trinotata</i> (Costa, 1858)	○							
<i>Dasylabris maura maura</i> (Linnaeus, 1758)	○							
POMPILIDAE								
<i>Pompilus cinereus</i> Fabricius, 1798			+					
<i>Agenioideus ciliatus</i> (Lepelletier, 1845)	+							
<i>Anoplius viaticus</i> (Linnaeus, 1758)	+							
<i>Aporus bicolor</i> Spinola, 1808	+							
<i>Auplopus carbonarius</i> (Scopoli, 1763)	+							
<i>Priocnemis (Priocnemis) propinqua</i> (Lepelletier, 1845)	+							
VESPIDAE EUMENINAE								
<i>Leptochilus (Neoleptochilus) regulus</i> (Saussure, 1855)			○					
<i>Stenodynerus fastidiosissimus</i> s. str. (Saussure, 1855)			○					
<i>Ancistrocerus auctus auctus</i> (Fabricius, 1793)	○							
<i>Ancistrocerus gazella</i> (Panzer, 1798)			○					
<i>Ancistrocerus longispinosus longispinosus</i> (Saussure, 1855)	○	○	●					
<i>Eumenes coarctatus maroccanus</i> Gusenleitner, 1972			○					
<i>Eumenes mediterraneus mediterraneus</i> Kriechbaumer, 1879	○		+					
<i>Delta unguiculatum</i> (Villers, 1789)	+							
<i>Rynchium oculatum</i> (Fabricius, 1781)			●					
VESPIDAE VESPINAE								
<i>Vespa crabro crabro</i> Linnaeus, 1758			+					
<i>Polistes (Polistes) dominula</i> (Christ, 1791)			+					
<i>Polistes (Polistes) gallicus</i> (Linnaeus, 1767)			+					
<i>Polistes (Polistes) nimpha</i> (Christ, 1791)			+					

<i>Vespula (Paravespula) germanica</i> (Fabricius, 1793)	+		+					
SPHECIDAE								
<i>Sceliphron destillatorium</i> (Illiger, 1807)							○	
<i>Sceliphron spirifex</i> (Linnaeus, 1758)			○					
<i>Ammophila heydeni</i> Dahlbom, 1845	+							
<i>Prionyx subfuscatus</i> (Dahlbom, 1845)	+							
<i>Prionyx lividocinctus</i> (A. Costa, 1858)	+							
<i>Sphex funerarius</i> Gussakovskij, 1934	+							
CRABRONIDAE								
<i>Dryudella esterinae</i> Pagliano, 2001	+							
<i>Dryudella tricolor</i> (Van der Linden, 1829)	+							
<i>Harpactus laevis</i> (Latreille, 1792)	+							
<i>Nysson quadriguttatus</i> Spinola, 1808			+					
<i>Crossocerus distinguendus</i> (Morawitz, 1866)	+							
<i>Crossocerus quadrimaculatus</i> (Fabricius, 1793)	+							
<i>Lestica clypeata</i> (Schreber, 1759)	+							
<i>Tracheliodes quinquenotatus</i> (Jurine, 1807)	+		+					
<i>Tachysphex costae</i> (De Stefani-Perez, 1882)			+					
<i>Tachysphex nitidior</i> Beaumont, 1940			+					
<i>Miscophus eatoni</i> Saunders, 1903			+					
<i>Miscophus lusitanicus</i> Andrade, 1952							+	
<i>Miscophus pretiosus</i> Kohl, 1884			+					
<i>Solierella compedita</i> (Piccioli, 1869)	+						+	
<i>Pison atrum</i> (Spinola, 1808)	+							
<i>Trypoxylon kolazyi</i> Kohl, 1893	+		+					
<i>Trypoxylon deceptorium</i> Antropov, 1991			+					
<i>Trypoxylon scutatum</i> Chevrier, 1867	+		+					
<i>Ammoplanus perrisi</i> Giraud, 1869	+							
<i>Ammoplanus (Ammoplanellus) simplex</i> Gussakovskij, 1952			○					
<i>Passaloecus pictus</i> Ribaut, 1952	+							
<i>Pemphredon austriaca</i> (Kohl, 1888)	+							
<i>Mimesa grandii</i> Maidl, 1933	+							
<i>Cerceris circularis dacica</i> Schletterer, 1887	+							
<i>Philanthus coarctatus siculus</i> Giordani Soika, 1944	+							
FORMICIDAE								
<i>Aphaenogaster pallida</i> (Nylander, 1848)	○	○			+			2+
<i>Aphaenogaster semipolita</i> (Nylander, 1856)	○	○			○		○	
<i>Aphaenogaster splendida</i> (Roger, 1859)				○				
<i>Aphaenogaster subterranea</i> (Latreille, 1798)	○	○		○	○	○	○	1+
<i>Camponotus aethiops</i> (Latreille, 1798)	○							
<i>Camponotus lateralis</i> (Olivier, 1791)	○	○	●	○	○		○	
<i>Camponotus micans</i> (Nylander, 1856)	●	○	○		○			
<i>Camponotus nylanderi</i> Emery, 1921	●	○	○	○	●	+	○	1● 4+
<i>Camponotus piceus</i> (Leach, 1825)	○							

<i>Camponotus ruber</i> Emery, 1925	○						○	
<i>Crematogaster scutellaris</i> (Olivier, 1791)	●	○	○	○	○		○	
<i>Crematogaster sordidula</i> (Nylander, 1849)		○					○	
<i>Formica cunicularia</i> Latreille, 1798	○							
<i>Lepisiota frauenfeldi</i> (Mayr, 1855)	○							
<i>Lepisiota nigra</i> (Dalla Torre, 1893)	○	○	○				○	1+
<i>Messor barbarus</i> (Linnaeus, 1767)		○						
<i>Messor bouvieri</i> Bondroit, 1918	○	○	○	○	○		○	
<i>Messor capitatus</i> (Latreille, 1798)	●							
<i>Messor ibericus</i> Santschi, 1931		○			○			
<i>Messor meridionalis</i> (André, 1882)	○							
<i>Messor minor</i> ssp. <i>calabricus</i> Santschi, 1927								2●
<i>Messor structor</i> (Latreille, 1798)	●							
<i>Nylanderia</i> sp.				○				
<i>Oxyopomyrmex saulcyi</i> Emery, 1889	○							
<i>Pheidole pallidula</i> (Nylander, 1848)	○	○	○	●	○		○	
<i>Plagiolepis pallescens</i> Lomnicki, 1925	○	○	○	○		○	○	1+
<i>Plagiolepis pygmaea</i> (Latreille, 1798)	○				○			
<i>Ponera coarctata</i> (Latreille, 1802)	○	○				●		
<i>Tetramorium bicarinatum</i> (Nylander, 1846)	○						○	
<i>Tetramorium diomedaeum</i> Emery, 1908					○			
<i>Tetramorium immigrans</i> Santschi, 1927							○	
<i>Tetramorium punctatum</i> Santschi, 1927	○	○	○	○	○		○	4+
<i>Tetramorium semilaeve</i> André, 1883	○	○	○	○	○	○	○	
<i>Lasius myops</i> Forel, 1894	○	○	○					
<i>Lasius casevitzi</i> Seifert & Galkowski, 2016	○	○				○		
<i>Lasius emarginatus</i> (Olivier, 1792)	○	○						
<i>Lasius lasioides</i> (Emery, 1869)	○	○	○	○	○	○	○	
<i>Linepithema humile</i> (Mayr, 1868)				○	○			
<i>Monomorium subopacum</i> (F. Smith, 1858)	○			○	○		○	
<i>Solenopsis fugax</i> (Latreille, 1798)	○							
<i>Solenopsis latro</i> Forel, 1894	○	○		○	○			
<i>Strongylognathus destefanii</i> Emery, 1915			○					
<i>Strumigenys membranifera</i> Emery, 1869				○				
<i>Tapinoma erraticum</i> (Latreille, 1798)	○	○	○					
<i>Tapinoma nigerrimum</i> complex	○	○	○	○	○		○	
<i>Temnothorax exilis</i> (Emery, 1869)	○	○	○	○	○	○	○	
<i>Temnothorax lichtensteini</i> (Bondroit, 1918)		○						
<i>Temnothorax mediterraneus</i> Ward, Brady, Fisher & Schultz, 2014	○		○	○	○		○	
<i>Wasmannia auropunctata</i> (Roger, 1863)								2?
COLLETIDAE								
<i>Colletes nigricans</i> Gistel, 1857		+						
<i>Hylaeus (Paraprosopis) clypearis</i> (Schenck, 1853)							+	
<i>Hylaeus (Dentigera) imparilis</i> Förster, 1871	+							
<i>Hylaeus (Spatulariella) punctatus</i> (Brullé, 1832)		+						

ANDRENIDAE								
<i>Andrena (Charitandrena) hattorfiana dimidiata</i> Brullé, 1832			+					
<i>Andrena (Euandrena) ruficrus</i> Nylander, 1848	+							
<i>Andrena (Melandrena) morio morio</i> Brullé, 1832			+				+	
<i>Andrena (Melandrena) nigroaenea</i> s.str. (Kirby, 1802)					+			
<i>Andrena (Melandrena) nitida nitida</i> (Müller, 1776)			+					
<i>Andrena (Plastandrena) pilipes</i> Fabricius, 1781			+					
<i>Andrena (Scitandrena) scita</i> Eversmann, 1852			+					
<i>Andrena (Taeniandrena) wilkella</i> (Kirby, 1802)			+					
HALICTIDAE								
<i>Pseudapis bispinosa</i> (Brullé, 1832)			+					
<i>Ceylaliectus variegatus</i> (Olivier, 1789)			+					
<i>Nomioides facilis</i> (Smith, 1853)	+							
<i>Nomioides minutissimus</i> (Rossi, 1790)			+					
<i>Halictus (Halictus) quadricinctus</i> (Fabricius, 1776)			+				+	
<i>Halictus (Hexataenites) fulvipes</i> (Klug, 1817)	+		+				+	
<i>Halictus (Hexataenites) scabiosae</i> (Rossi, 1790)	+							
<i>Halictus (Monilapis) compressus</i> Walckenaer, 1802	+							
<i>Halictus (Seladonia) gemmeus</i> Dours, 1872			+					
<i>Halictus (Seladonia) smaragdulus</i> Vachal, 1895			+					
<i>Halictus (Tytthaliectus) asperulus</i> Perez, 1895			+				+	
<i>Halictus (Tytthaliectus) maculatus</i> Smith, 1848							+	
<i>Lasioglossum (Dialictus) nitidulum</i> (Fabricius, 1804)	+							
<i>Lasioglossum (Dialictus) planulum</i> (Perez, 1903)	+							
<i>Lasioglossum (Dialictus) semilucens</i> (Alfken, 1914)	+							
<i>Lasioglossum (Sphecodogastra) immunitum sillatum</i> (Warncke, 1981)			+					
<i>Lasioglossum (Sphecodogastra) malachurum</i> (Kirby, 1802)	+							
<i>Lasioglossum (Sphecodogastra) opacum</i> Perez, 1895	+		+					
<i>Lasioglossum (Sphecodogastra) nigripes</i> (Lepelletier, 1841)	+							
<i>Lasioglossum (Sphecodogastra) pauxillum</i> (Schenck, 1853)							+	
<i>Lasioglossum (Sphecodogastra) subhirtum</i> (Lepelletier, 1841)	+							
<i>Lasioglossum (Lasioglossum) albocinctum</i> (Lucas, 1849)			+					
<i>Lasioglossum (Lasioglossum) bimaculatum</i> (Dours, 1872)	+		+					
<i>Lasioglossum (Lasioglossum) costulatum</i> (Kriechbaumer, 1873)	+							
<i>Lasioglossum (Lasioglossum) leucozonium cedri</i> Ebmer, 1976	+							
<i>Sphecodes albilabris</i> (Fabricius, 1793)	+							
<i>Sphecodes gibbus</i> (Linnaeus, 1758)			+					
<i>Sphecodes monilicornis quadratus</i> Meyer, 1919			+					
<i>Sphecodes spinulosus</i> Hagens, 1875			+					
MEGACHILIDAE								
<i>Heriades (Heriades) truncorum</i> (Linnaeus, 1758)			+					
<i>Hoplitis (Hoplitis) adunca adunca</i> (Panzer, 1798)			+					
<i>Hoplitis (Hoplitis) lepeletieri</i> (Panzer, 1798)			+					
<i>Osmia (Helicosmia) latreillei iberoafricana</i> Peters, 1975			+		+			
<i>Osmia (Pyrosmia) submicans hebraea</i> Benoist, 1934			+					

<i>Rhodanthidium septemdentatum</i> (Latreille, 1809)	+							
<i>Stelis phaeoptera murina</i> Perez, 1884	+							
<i>Dioxys cincta</i> (Jurine, 1807)	+							
<i>Megachile</i> (<i>Chlicodoma</i>) <i>parietina</i> (Geoffroy, 1785)	+						+	
<i>Megachile</i> (<i>Chalicodoma</i>) <i>sicula</i> Rossi, 1792	+							
<i>Megachile</i> (<i>Eutricharaea</i>) <i>apicalis</i> Spinola, 1808	+		○					
<i>Megachile</i> (<i>Eutricharaea</i>) <i>pilidens</i> Alfken, 1924			●					
<i>Anthidium manicatum</i> (Linnaeus, 1758)			○					
<i>Anthidium florentinum</i> (Fabricius, 1775) ¹				○				
APIDAE								
<i>Xylocopa</i> (<i>Xylocopa</i>) <i>valga</i> Gerstaecker 1872				○				
<i>Xylocopa</i> (<i>Xylocopa</i>) <i>violacea</i> (Linnaeus, 1758)	●		●	○	○		○	
<i>Ceratina cucurbitina</i> (Rossi, 1792)	+		+			+		
<i>Nomada fulvicornis</i> Fabricius, 1793			+					
<i>Epeolus julliani</i> Perez, 1884			+					
<i>Pasites maculatus</i> Jurine, 1807			+					
<i>Eucera</i> (<i>Eucera</i>) <i>nigrescens</i> Perez, 1879			+			+		
<i>Tetraloniella dentata</i> (Germar, 1839)			+					
<i>Amegilla albigena</i> (Lepelletier, 1841)			+					
<i>Amegilla garrula</i> (Rossi, 1790)	+	+						
<i>Thyreus ramosus</i> (Lepelletier, 1841)								3+
<i>Anthophora</i> (<i>Lophanthophora</i>) <i>dispar</i> Lepelletier, 1841			○			○		
<i>Anthophora</i> (<i>Anthophora</i>) <i>plumipes niger</i> (Friese, 1896)			+					
<i>Bombus</i> (<i>Bombus</i>) <i>terrestris</i> (Linnaeus, 1758)			●					
<i>Apis mellifera</i> (Linnaeus, 1758)	●							

Table 1. Summary of Hymenoptera from Aeolian archipelago. Legend: ○ = bibliographic record only; ● = record confirmed by the present study; + = new record; ? = doubtful record. Islets: 1 = Strombolicchio; 2 = Lisca Bianca; 3 = Basiluzzo; 4 = Scoglio Faraglione. 1 observed and photographed in Stromboli as reported on 06.07.2011, https://www.naturamediterraneo.com/forum/topic.asp?TOPIC_ID=146201.

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***Buprestis splendens* (Fabricius, 1774) (Coleoptera Buprestidae) on the Calabrian side of the “Parco Nazionale del Pollino” (Calabria, Italy): distribution and ecological observation**

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ABSTRACT

Buprestis splendens (Fabricius, 1774) (Coleoptera Buprestidae) is a rare European chorotype species, threatened throughout its distribution by global climate change, forest fires and the capture of specimens by collectors. To date, in Italy, its presence was only known in a few areas on the Lucanian side of the massif of Pollino. This report records the first, reliable sightings of its presence on the Calabrian side of the Pollino and in the mountains of Orsomarso. It also makes observations on its environment and the factors that put its survival at risk.

KEY WORDS

Coleoptera; *Buprestis splendens*; distribution; Pollino massif; Orsomarso mountains; Calabria.

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INTRODUCTION

Buprestis splendens (Fabricius, 1774) (Coleoptera Buprestidae) is a rare European chorotype species, known in just a few sites in Russia, Finland, Poland, Albania, Bosnia-Erzegovina, Greece, Italy and Spain. Information on its environment and biology is scarce. It favours fresh climates and is linked to ancient conifers, in particular the Scotts Pine (*Pinus sylvestris* Linnaeus), the Black Pine (*Pinus nigra* Arnold) and the Bosnian Pine (*Pinus heldreichii* Christ subsp. *leucodermis* Antoine). The female lays her eggs on the dead trees and the larvae feed on the rotting wood. In the southern part of its range, the period of maximum activity by adults seems to coincide with the month of August (Mason et al., 2010; Trizzino et al., 2013; Curletti et al., 2016). In Italy, it is a strictly mountain species, ranging as far as 2000 m asl around the Bosnian Pine. There

are few indications of its presence, all limited to the Lucanian side of the Massiccio del Pollino (Gobbi, 1973; Izzillo, 1989; Curletti, 1994; 2007). It is currently one the coleopteran species most at risk in Europe, threatened by the illegal felling of old trees, from forest fires and from the sale of specimens to collectors. For these reasons, *B. splendens* is included in paragraphs II and IV of the Directive 92/437/CEE (attached). It is considered ‘Endangered’ at global level (Mason et al., 2010), ‘Vulnerable’ in the Mediterranean region (Garcia et al., 2018) and ‘Endangered’ in Italy (Rondinini et al., 2013).

In 2018 and 2019, in a study on species of insects of interest to the European community present in the areas of Rete Natura 2000, one of our team (S. Piazzini) conducted accurate research on the presence and distribution of *B. splendens* on the Calabrian side of the National Park of Pollino. The study was promoted and approved by the Depart-

ment of the environment and Territory of the Region of Calabria and the Institution of the National Park of Pollino.

MATERIAL AND METHODS

Study area

The Calabrian side of the National Park of Pollino stretches over 103,915 hectares of the total protected area of 192,565 hectares, part of which is also in Basilicata. It is a vast area, entirely within the province of Cosenza, extending from the top of the valley of the river Lao (Laino Borgo) in the north and the Ciagola range of mountains, as far as the crest of the Pollino range, in the south including all the Orsomarso mountains between Orsomarso and Serra La Vriglia in Belvedere Marittimo. Research in relation to *B. splendens* is concentrated to areas of formations of Bosnian pines at higher altitudes. These are Monte Pollino (2248 m), Serra Dolcedorme (2267 m), Serra delle Ciavole and Monte Manfria (Pollino range), La Montea (1827 m) and Monte La Caccia (1760 m) (Orsomarso mountains).

In this area, geologically, the substrate is almost entirely calcareous and relates to three carbonate units: Lungro-Verbicaro, Pollino-Ciagola and Cetraro (Iannace et al., 2005; 2007). The vegetation comprises woodland - predominantly beech (*Fagus sylvatica* Linnaeus); mesophytic beech (from 1300-1400m), microthermal beech (up to 2000 m). Above this level there are mesophytic mountain pastures and high mountain xeric grasslands.

Of particular interest are the formations of conifers at high altitude, dominated by Bosnian pines, (*Pinus heldreichii*). These are found particularly on the crests and the steepest slopes which have rocky substrates (Avena & Bruno, 1975; Gargano et al. 2012). Considering the ecological requirements of *Buprestis splendens*, research has been carried out exclusively at the highest points of the National Park where these coniferous trees grow; Monte Pollino (2248 m), Serra Dolcedorme (2267 m), Serra delle Ciavole and Monte Manfria, in the Pollino range; La Montea (1827 m) and Monte La Caccia (1760 m), in the Orsomarso mountains.

Methods of sampling

Eleven areas have been identified where there are adult dead or decaying trees potentially providing suitable habitat for *B. splendens*. Each of these areas was visited on at least four occasions between July and September 2018 and June and August 2019. Using an experimental method suggested by Curletti et al. (2016) (not developed or tested prior to this study), the species was sampled through direct observation of exit holes on dead or decaying Bosnian pines. This method was adapted in the field. Initially, surveys were conducted in sample areas of around 5000 sqm in which there were at least ten dead or decaying trees showing exit holes made by *B. splendens*. In each area at least three trees were marked by a cairn built at the base, noting the exact position using GPS coordinates. The three specimens showed at least 150 flickering holes, some of which were recent and recognisable by the light colour inside. The holes were circled using a coloured, indelible pen. The marking was done twice - once at the end of summer 2018 and once at the beginning of summer 2019 as in some cases the marking had weathered over the winter. It is advisable to leave the marking in May and the first half of June.

RESULTS AND DISCUSSIONS

The presence of the species has been confirmed in six of the eleven areas visited (Table 1).

1. The southern ridge of the Serra delle Ciavole (SIC IT310013 Serra of the Ciavole-Serra, Crispo) at 1900 m asl and at 2040 m asl.
2. Two sites on the southern range of the Serra Dolcedorme (SIC IT9310003 Pollinello-Dolcedorme).
3. In proximity of the Passo del Vascello at 2050 m and at 1980 m on the southern side.
4. Monte Pollino on rock formations west of the Pollinello valley at 1970 m.
5. Orsomarso mountains on the eastern crest of La Montea, at 1750 m.

The above include the first confirmed sightings in Calabria and the first ever in the Orsomarso mountains.

The species has not been detected on Monte Manfria or Monte La Caccia despite the habitat



Figure 1 (left). *Buprestis splendens* (Fabricius, 1774), Serra delle Ciavole, 8.08.18 (photo M. Di Luca).

Figure 2 (right). Marking of exit holes with indelible pen (photo S. Piazzini)

being considered appropriate. On Monte Manfria, a number of dead trees have been identified on which there are exit holes relating to *B. splendens* but it has not been possible to verify its presence.

That does not exclude the possibility that the species is present and may be discovered as research continues. On the other hand, it is probable that on Monte La Caccia, *B. splendens* has recently become extinct due to an extensive forest fire a few years ago and an increase of temperatures due to climate change making the environment less favourable for the species. Indeed *B. splendens* is linked to mountains and cooler climates to the south of its range of distribution (Trizzino et al., 2013).

An accurate evaluation of the population is only possible through studies carried out over a number of years (at least five). From current data indicating the number of specimens discovered and the number of new exit holes observed, we can confirm that in the areas investigated, the species is present in metapopulations, each made up of tens of specimens.

The areas where *B. splendens* is found are all at high altitudes, ranging from 1750 m to 2100 m. These areas are predominately rocky and populated by formations well structured of Bosnian pines with contemporary presence of ancient, dead and decaying trees, standing and fallen. Observation of exit holes and specimens indicates that the species tends to colonise mostly the basal and decaying parts of older trees and broken trunks of pines both standing and fallen. Contrary to Koch's belief (1989), it appears to avoid wood that is excessively rotten and decomposed. *B. splendens* also appears to show a certain preference for trees, or parts of trees that have been struck by lightning and partially burnt. According to available data, adult emerging seems to happen from the end of June in lower areas and throughout July at higher levels. In the areas investigated, what most threatens the survival of *B. splendens* are forest fires, collecting of specimens and global climate change. Indeed the species was detected only at very high altitudes (above 1700 m), while in the sites monitored at lower altitudes it was not ascertained and probably extinct in

Locality	Geographic coordinates	Altitude	Date	Evidence
Serra delle Ciavole (Cerchiara di Calabria, CS)	39°54'N - 16°13'E	1900 m	27.07.18	
			1 specimen dead	
			08.08.18	1 female
			13.08.18	
			06.09.18	
			14.06.19	
			09.07.19	
			27.07.19	1 new exit hole
Serra delle Ciavole (Cerchiara di Calabria, CS)	39°54'N - 16°13'E	2040 m	27.07.18	
			08.08.18	
			13.08.18	
			06.09.18	
			14.06.19	
			09.07.19	
			27.07.19	2 new exit holes
Serra Dolcedorme (Castrovillari, CS)	39°53'N - 16°13'E	2050 m	27.07.18	
			08.08.18	1 female + 2 new exit hole with fresh sawdust
			13.08.18	
			14.06.19	
			27.07.19	
			13.08.19	1 new exit hole
Serra Dolcedorme (Castrovillari, CS)	39°53'N - 16°13'E	1980 m	27.07.18	
			08.08.18	
			13.08.18	
			14.06.19	
			27.07.19	1 new exit hole
			13.08.19	
Monte Pollino (Castrovillari, CS)	39°53'N - 16°11'E	1950 m	26.08.18	
			14.06.19	
			08.07.19	
			24.07.19	
Monte Pollino (Morano Calabro, CS)	39°54'N - 16°11'E	1970 m	26.08.18	
			14.06.19	
			08.07.19	
			24.07.19	1 exit hole
Monte Manfriana (Frascineto, CS)	39°52'N - 16°14'E	1945 m	26.06.19	
			13.07.19	
			27.07.19	
			10.08.19	
La Montea (Mottafollone, CS)	39°39'N - 15°57'E	1685 m	25.07.18	
			11.08.18	
			23.08.18	
			12.06.19	
			14.07.19	
			11.08.19	

Montea, cresta sudest (Mottafollone, CS)	39°39'N - 15°56'E	1750 m	25.07.18	
			11.08.18	
			23.08.18	
			12.06.19	
			14.07.19	1 new exit hole
			11.08.19	
Monte La Caccia (Belvedere Marittimo, CS)	39°39'N - 15°55'E	1550 m	23.08.18	
			12.06.19	
			14.07.19	
			07.08.19	
Monte La Caccia (Belvedere Marittimo, CS)	39°39'N - 15°55'E	1385 m	23.08.18	
			12.06.19	
			14.07.19	
			07.08.19	

Table 1. Examined localities with suitable habitats and evidence of the species. For conservation reasons, the exact location of discovery sites is not indicated, and the seconds are omitted in the geographical coordinates.

recent times precisely because of global warming (as demonstrated in Spain) (Hernandez-Manrique et al., 2013).

Taking the above into account it is clear that the conservation of *B. splendens* in Italy is problematic. Considering the difficulty, if not impossibility of taking actions that would effectively mitigate the negative effects of climate change, what could and should be done to conserve the populations would be to increase controls over the entirety of the National Park, to prevent fires and stop the collection of insects. It would be constructive to extend the research to the Lucanian side of the protected area. With more precise information of the distribution and size of the population of this species, further interventions towards its conservation could be proposed.

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First record of *Zaprionus indianus* (Gupta, 1970) (Diptera Drosophilidae) from Bangladesh

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ABSTRACT

Zaprionus indianus (Gupta, 1970) (Diptera Drosophilidae), also known as African fig fly, is considered as the primary pest only to fig fruits along with secondary pest to other fruits. Its occurrence has been reported from many countries but not previously reported from Bangladesh. With this note, we report here the first observation of *Z. indianus* from Bangladesh. Fly samples were collected by using yeast-banana traps. The species was identified by morphological characteristics and mitochondrial COI gene sequence.

KEY WORDS

African fig fly; Bangladesh; *Zaprionus indianus*.

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INTRODUCTION

Zaprionus indianus (Gupta, 1970) (Diptera Drosophilidae), commonly known as African fig fly, belongs to the genus *Zaprionus* Coquillett, 1902 which contains a total of 57 species (Yassin & David, 2010). This fly has brown body of approximately 2.5 to 3.0 mm in length along with red eyes. However, they have a pair of distinctive silvery-white stripes with black borders on the top of the head to the tip of the scutellum as well as laterally from the forefront of the thorax to the base of each wing. *Zaprionus indianus* was first described from India in 1970 (Gupta, 1970). Though this fly was thought to be originated from tropical Africa (Chassagnard & Kraaijeveld, 1996), at present it has spread in many parts of the world including from old to new world countries (Commar et al., 2012). At present, the geographical distribution of *Z. indianus* is considered as cosmopolitan (Tidon et al., 2003). Though this fly is being reported from different parts of the world including some Asian countries (Commar et al.,

2012), but there is no previous record from Bangladesh.

In this paper, we report the occurrence of *Z. indianus* from Bangladesh for the first time.

MATERIAL AND METHODS

Flies were collected during a field sampling from Natore (24°26'26.5"N; 89°00'36.7"E), a northern district of Rajshahi division of Bangladesh (Fig. 1). Yeast-banana traps were used to collect them. Flies were reared and maintained on food made with semolina yeast. Morphological identification was done by observing the 4 to 6 composite spines on the fore femur along with the prominent pair of silvery-white stripes (Gupta, 1970). For further confirmation, molecular identification was conducted by partially sequencing the mitochondrial COI gene. Universal primer pairs LCO1490 (forward) and HCO2198 (reverse) were used for PCR amplification after extracting the DNA (Folmer et al., 1994). Sequence file was submitted to

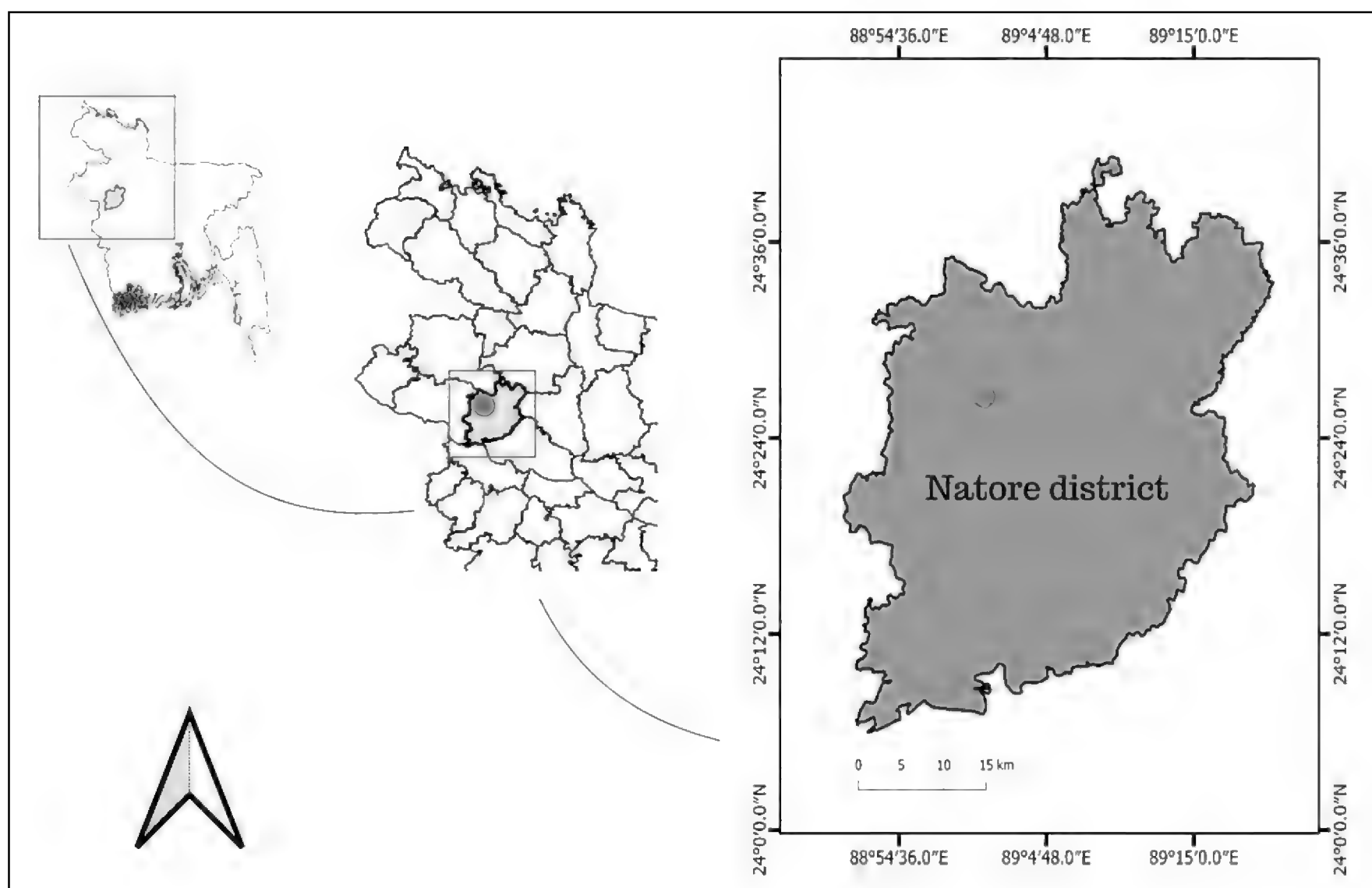


Figure 1. Distribution of *Zaprionus indianus* in Bangladesh. The red dot denotes the exact location from where the fly was collected.

NCBI GenBank (Accession no. MN863530.1). Specimens were preserved at the Genetics and Molecular Biology Laboratory, Department of Zoology, University of Dhaka.

RESULTS

Systematics

Phylum ARTHROPODA von Siebold, 1848
 Classis INSECTA Linnaeus, 1758
 Ordo DIPTERA Linnaeus, 1758
 Familia DROSOPHILIDAE Rondani, 1856
 Genus *Zaprionus* Coquillett, 1902

Zaprionus indianus (Gupta, 1970) Figs. 2-4

Collected flies were first identified as *Z. indianus* by observing the longitudinal silvery-white stripes (Fig. 2) along with the spines on the fore femur (Fig. 3) (Gupta, 1970). This was further confirmed

by the result of partial sequencing of the mitochondrial COI gene. Amplified sequence was approximately 630 bp in length. Basic Local Alignment Search Tool (BLAST) of National Center for Biotechnology Information (NCBI) was used to check similarity between our sequence and GenBank database of sequences. BLAST result revealed that our observed sequence showed 99.52% similarity with the sequence of *Z. indianus* in GenBank from Israel and India (Accession no. KC994626.1 and EF632366.1 respectively) along with 99.37% similarity with the sequences of the same species in GenBank from India, Saudi Arabia and Egypt (Accession no. EF632367.1, EF632365.1 and EF632362.1 respectively). This confirmed that our collected species is *Zaprionus indianus*.

DISCUSSION AND CONCLUSION

Zaprionus indianus is reported as primary pest only to fig fruits along with secondary and a serious aggressive pest to more than 80 different fruits

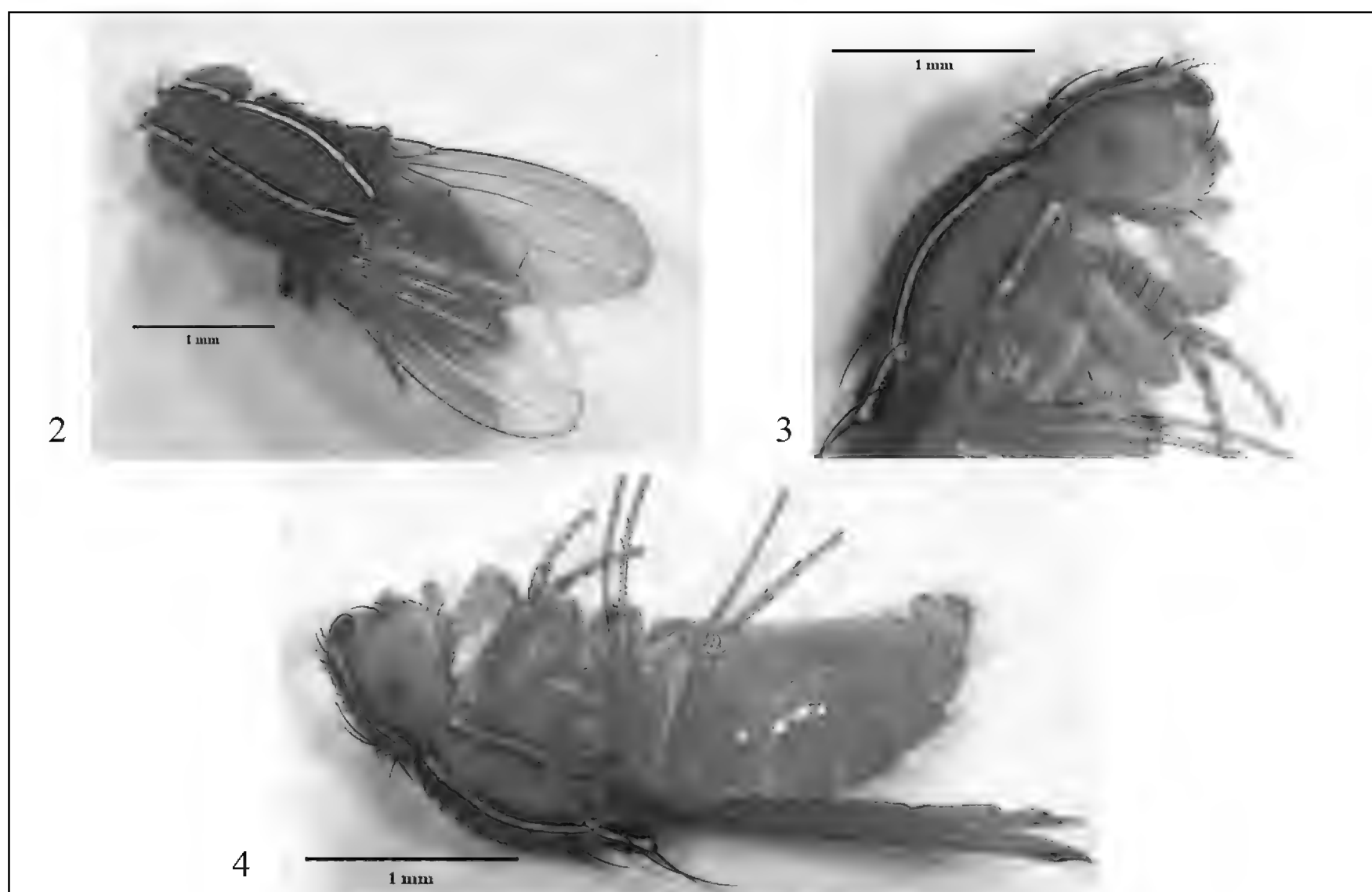


Figure 2. *Zaprionus indianus* (Gupta, 1970) collected from Natore, Bangladesh, dorsal view.

Figure 3. Idem, composite spines on the fore femur. Figure 4. Idem, lateral view.

(Yassin & David 2010; Van der Linde et al., 2006). Being considered as cosmopolitan species, this fly is widely distributed throughout many different countries of the world (Karan et al., 2000). It was thought that the genus *Zaprionus* appeared first in the Oriental region during the Late Miocene. Immediately after that, it spread to the West Africa during the Quaternary through the Indian Ocean (Yassin et al., 2008). Most of the morphological and ecological modifications took place there due to different climatic conditions. Global trade of fruits can be a major reason of why they are so widely distributed. As one of the most widespread species of the genus *Zaprionus*, this species occurs over a broad range in Asia along with Africa and the Americas (Commar et al., 2012). Though its occurrence has been reported from neighboring India and Pakistan (Gupta, 1970; Shakoori & Butt 1979; Commar et al., 2012), its presence in Bangladesh has not been reported previously. The survey area (Natore under Rajshahi Division) is located at the northern part of Bangladesh near Indian border. Thus it has a great chance that this fly might invade from India either

by fruit trading or by other ways. Our present study shows the presence of *Z. indianus* from Bangladesh for the first time. As they have potential role in damaging different fruits, further study will be useful.

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***Callidiellum rufipenne* (Motschulsky, 1860) new longhorn beetle to the fauna of Bosnia and Herzegovina and Slovenia (Coleoptera Cerambycidae)**

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ABSTRACT In this paper the authors record for the first time the invasive species *Callidiellum rufipenne* (Motschulsky, 1860) (Coleoptera Cerambycidae) for the fauna of the republics of Bosnia and Herzegovina and Slovenia.

KEY WORDS Cerambycidae; *Callidiellum*; new record; Bosnia and Herzegovina; Slovenia.

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INTRODUCTION

Invasive longhorn beetles (Coleoptera Cerambycidae) have been present in Europe for a relatively long time. However, in the last two to three decades the number of these invasive insects in Europe has risen exponentially due to increased international trade of goods which created new and rapid transport pathway opportunities (Cocquempot & Mifsud, 2013). To this effect, in these last twenty years, 19 species of alien longhorn beetles have been introduced and established in Europe, and some 20 other species have been intercepted or recorded, but so far not naturalized (Cocquempot, 2007; Cocquempot & Lindelöw, 2010).

Recent increases in commercial traffic from Asia (especially China) to Europe has accounted for the introduction of a number of new species of cerambycids as *Callidiellum rufipenne* (Motschulsky, 1860).

In this paper we present first record of *Callidiellum rufipenne* for Bosnia and Herzegovina and Slovenia.

RESULTS

Systematics

Ordo COLEOPTERA Linnaeus, 1750
Superfamilia CHRYSOMELOIDEA Latreille, 1802
Familia CERAMBYCIDAE Latreille, 1802
Tribus CALLIDIINI Mulsant, 1839
Genus *Callidiellum* Linsley, 1940

***Callidiellum rufipenne* (Motschulsky, 1860)**

EXAMINED MATERIAL. BOSNIA and HERZEGOVINA: Bijeljina, 44.760168°N 19.211951°E, 1 female, 24.04.2017, A. Đukić legit, det. P. Rapuzzi; SLOVENIA: 1 male, Obrov, Poljane env. (KP), X.2002, ex ovo *Thuja* sp., emerged VI.2006, J. Vávra legit (coll. P. Rapuzzi).

DESCRIPTION. The adults look (Fig. 1) like small *Callidium* Fabricius, 1775 ranging from 7 to 13 mm. The head, thorax and all appendages are

black, abdomen is red and the elytra are generally dark red more or less iridescent. However, the color of the elytra males is quite variable. The color varies from red to blue-purple or green. Medial black coloring of the large part of elytra is also common, especially pronounced in males. (Maier & Lemmon, 2000).

DISTRIBUTION. *Callidiellum rufipenne* is native to Asia, occurring in China, Japan, Korea, the Russian Far East, and Taiwan (Duffy, 1968; Danilevsky 2015; EPPO 2015). Its introduction was detected for the first time in Italy, in the port of Ravenna in March 1988 (Campadelli & Sama, 1988). Other established populations of *C. rufipenne* in Europe populations were recorded in Spain (Bahillo de la Puebla & Iturrondobeitia-Bilbao, 1995), Belgium (Verbeelen, 2007), Croatia on the island of Krk (Los & Plewa, 2011), France (Van Meer & Cocquempot, 2013). Besides Europe, this beetle was accidentally introduced to Argentina (Turienzo, 2006), Canada (Vancouver), New Zealand and Puerto Rico. In the United States, the beetle has been detected in Washington in 1954 and more recently in the Northeast (Connecticut, Massachusetts, New Jersey, New

York, North Carolina and Rhode Island) (Aphis, 1999; Pasek, 2000).

BIOLOGY. Larvae bore into coniferous trees of the cypress family, Cupressaceae. Major hosts include arborvitae (*Thuja*), juniper (*Juniperus*) and cedar (*Chamaecyparis*). Beetles normally colonize weakened or freshly felled trees. However, in Connecticut, the beetle has been observed completing development in apparently healthy arborvitae (Maier, 2007). *Callidiellum rufipenne* is a univoltine species in native and large part of alien distribution. Nevertheless, bivoltine behavior was recorded by Van Meer & Cocquempot (2013) who stated that *C. rufipenne* has some plasticity over the course of its development probably according to climatic criteria. Adults emerge in spring, mate on the bark surface of host trees, and soon begin to oviposit in bark cracks and crevices. Adults apparently do not feed, and typically live for two to three weeks. Eggs hatch in about two weeks and larvae immediately tunnel through the bark and feed in the cambial region. Mature larvae enter the wood in late summer and construct a cell at the end of their galleries in which they pupate. Pupation occurs in autumn, with adults overwintering within the hosts and emerging through oval-shaped exit holes the following spring (Haack, 2017).

REMARKS. Unlike introduction of *C. rufipenne* in France that could be due to expansion from the Spanish populations (Van Meer & Cocquempot, 2013), record of *C. rufipenne* in Bosnia and Herzegovina and Slovenia are probably new cases of introduction caused by import of industrial wood or products manufactured from the Asian continent.

Callidiellum rufipenne generally is considered a secondary pest, primarily infesting weakened or recently dead trees (Shibata, 1994). However, in the eastern United States, *C. rufipenne* occasionally has infested living *Chamaecyparis*, *Juniperus*, and *Thuja* trees and shrubs (Maier & Lemmon, 2000; Maier, 2007) and it was found attacking apparently healthy *Thuja* nursery stock in Connecticut (Maier & Lemmon, 2000). This species has been added to the alert lists of EPPO (European Organization for Plant Protection) in 1999, following the Italian introductions, but it was removed after 5 years due to the absence of damage and its secondary pest character (Van Meer & Cocquempot, 2013).



Figure 1. Female of *Callidiellum rufipenne* from Bosnia and Herzegovina.

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At last at home: a correct taxonomic assignment and a proper repository for the holotype of *Acirsa corsicana* Nordsieck, 1974 (Caenogastropoda Epitonidae)

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ABSTRACT

The taxonomic composition of the family Epitoniidae Berry, 1910 (1812) in Italian waters underwent relatively few changes in recent decades: except some nomenclatural changes and one reinstatement, only few species have been recently added to this fauna. *Acirsa corsicana* Nordsieck, 1974 is the last taxon described in the area and its status is currently disputed or wrongly assessed. After the examination of the holotype and comparisons with similar species, the status of *A. corsicana* is here properly assessed as junior synonym of *Opalia coronata* (Philippi & Scacchi, 1840). The specimen, until now kept in private collections, is deposited in an institutional repository (MNHN).

KEY WORDS

Mollusca; Gastropoda; Mediterranean Sea; taxonomy; type material.

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INTRODUCTION

The taxonomic composition of Epitoniidae Berry, 1910 (1812) in Italian waters has been relatively stable since decades. The revision of North-East Atlantic and Mediterranean bathyal representatives of this family by Bouchet & Warén (1986) dealt with many species recorded from this area. Subsequently, a comprehensive national checklist summarized the knowledge of the time (Oliviero, 2008). Except for the addition of the genus *Janthina* Röding, 1798 (Beu, 2017), some nomenclature changes and one revalidation (Gittenberger & Gittenberger, 2005; Crocetta et al., 2015; Appoloni et al., 2018), only three taxa have been recently added to this fauna (Smriglio et al., 1996; Romani & Bogi, 2014; Scaperrotta et al., 2018), none of them new to science.

Acirsa corsicana Nordsieck, 1974 is the last

species described in the area. It was established on a single incomplete shell and its status was soon disputed and subsequently neglected or wrongly assessed. The holotype, until now kept in private collections, is here re-examined and compared with similar species. Its actual status is clarified and it is deposited in an institutional repository.

MATERIAL AND METHODS

Material was collected from bioclastic bottoms by SCUBA diving or obtained through the analysis of by-catch of commercial trawling. Comparisons were done with material figured in recent papers and samples from several localities (see below). Shells were examined through Lomo MBC-10 stereomicroscope and photographed with a Canon EOS 400D camera, while measure-

ments were carried out by means of an eyepiece micrometer.

Updated taxonomy and nomenclature follow MolluscaBase (2020) except where otherwise stated.

ABBREVIATIONS AND ACRONYMS. AP: Attilio Pagli private collection (Empoli, Italy); H: total height; ICZN: International Code of Zoological Nomenclature; LR: Luigi Romani private collection (Lucca, Italy); MNHN: Muséum National d'Histoire Naturelle (Paris, France); SB: Stefano & Maria Bartolini private collection (Firenze, Italy); W: total width.

RESULTS

Systematics

Phylum MOLLUSCA Cuvier, 1797
Classis GASTROPODA Cuvier, 1795
Subclassis CAENOGASTROPODA Cox, 1960
Ordo [unassigned] CAENOGASTROPODA Cox, 1960
Familia EPITONIIDAE Berry, 1910 (1812)
Genus *Opalia* H. Adams et A. Adams, 1853

Opalia coronata (Philippi et Scacchi, 1840)

Acirsa corsicana F. Nordsieck, 1974 syn. nov.

EXAMINED MATERIAL. *Acirsa corsicana* Nordsieck, 1974: one shell (holotype), off Capo Comino (Nuoro, Sardinia), 1973, 200–220 m, found in a brachiopod-rich bottom sample (“detriti a *Terebratulula vitrea*” in the original label) (AP, ex Fulvio Giannini collection).

Acirsa subdecussata (Cantraine, 1835): 7 shells (4 adults and 3 juveniles), off Capraia Island (Livorno, Italy), 250 m (LR); 2 juvenile shells, off Motril (South Spain), 150 m (LR); one juvenile shell, Brač island (Dalmatia, Croatia), 60 m (SB); one shell, off Civitavecchia (Roma, Italy) 100 m (AP); 13 shells (adults and juveniles), off Capraia Island (Livorno, Italy), 150 m (AP); 2 shells, Barcellona (Catalonia, Spain), 45 m (AP).

Opalia coronata (Philippi et Scacchi, 1840): 5 shells, off Motril (Andalucia, Spain), 110 m (AP); 5 shells (one juvenile and 4 adults), Cannizzaro (Catania, Sicily, Italy), 40 m (LR and AP); 2 shells, off Gozo (Malta), 60 m (LR); one juvenile shell, off

E Crete (Greece), 70/110 m (LR); 7 shells (adults and juveniles), Haifa bay (Israel), 15 m (AP).

ORIGINAL DESCRIPTION. The fonts of scientific names are reproduced as in the original text: Nordsieck, 1974: “*Acirsa* (*Plesioacirsa*) *corsicana* n. sp. 3,2/1,5 mm. Monotipo nella coll. Giannini. Questa nuova specie differisce dall’unica *Plesioacirsa* conosciuta (e precisamente *subdecussata* CANTRAINE = *pelagica* RISSO) per i seguenti particolari: 1) i giri più convessi, solo un po’ compressi superiormente; 2) essi sono fittamente costulati, ma le costole, alcune delle quali formanti varici, sono obsolete: i 16 intervalli fra le costole sono larghi e piani; 3) invece di trattini spirali la nostra specie ha fini punteggiature spirali, circa 20 sull’ultimo giro. Il colore è da bianco a bianco-giallastro. Il monotipo (juvenile) ha circa 5 giri, ma l’apice è rotto. La conchiglia adulta può avere 9–10 giri e un’altezza massima di 8–10 mm. *Acirsa corsicana* n. sp. è strettamente collegata con la miocenica *Plesioacirsa mioplicatula* (KAUTSKY 1925) (v. Vol. IV “The Miocene Molluscs-fauna ecc. Nr. 42, p. 59) ma quest’ultima specie non ha le punteggiature spirali”.

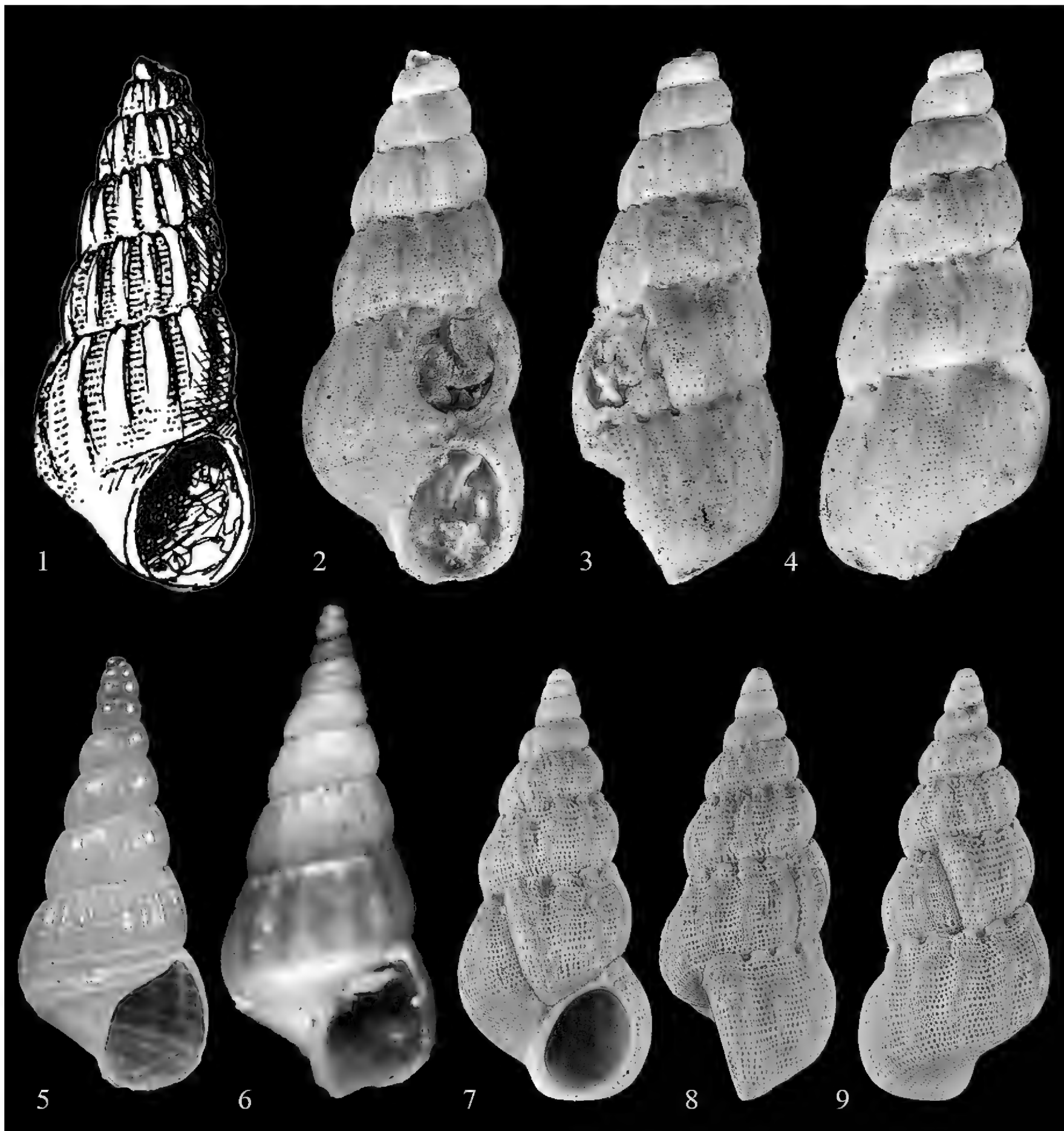
English translation. *Acirsa* (*Plesioacirsa*) *corsicana* n. sp. H: 3.2 mm, W: 1.5 mm. Monotype in the Giannini collection. This new species differs from the only known *Plesioacirsa* (and precisely *subdecussata* Cantraine = *pelagica* Risso) for the following details: 1) the more convex whorls, only slightly compressed at the top; 2) they are thickly ribbed, but the ribs, some of which forming varices, are obsolete: the 16 intervals between the ribs are wide and flat; 3) instead of spiral grooves, our species has fine spiral punctuations, about 20 on the last whorl. The color is white to yellowish-white. The monotype (juvenile) has about 5 whorls, but the apex is broken. The adult shell can have 9–10 whorls and a maximum height of 8–10 mm. *Acirsa corsicana* n.sp. is closely connected with the Miocene *Plesioacirsa mioplicatula* (Kautsky, 1925) (see Vol. IV “The Miocene Molluscs-fauna etc. Nr. 42, p. 59) but the latter species does not have spiral punctuations.

ADDITIONAL DESCRIPTION. The single *A. corsicana* specimen is a quite worn, incomplete shell (Figs. 2–4), whose overall features were outlined in the original description (see above) and drawing (Fig. 1). Some corrections and further details can be added: the actual height is 3.6 mm. An apparent

“basal keel” on the last part of the body whorl is indeed the remnant of the fractured shell wall. On the last whorl there is a predation hole not reproduced in the drawing. The suture is deep. The slightly sigmoid axial ribs protrude adapically and adhere to the previous whorls, so producing an evident crenulation at the suture level. The external surface appears

chalky and sculptured due to the presence of an evident intritacalx. This, although partially abraded, consists of microscopic holes spirally arranged that give a pitted appearance to the surface.

REMARKS. Soon after its description, *A. corsicana* was synonymized with *Acirsa subdecussata*



Figures 1–9. Fig. 1: *Acirsa corsicana* holotype drawing, from Nordsieck (1974) modified. Figs. 2–4: *Acirsa corsicana* holotype, 3.6 mm, off Capo Comino (Nuoro, Sardinia, Italy), 200–220 m. Fig. 5: *Acirsa subdecussata* juvenile shell, 2.7 mm, Brač island (Dalmatia, Croatia), 60 m. Fig. 6: “*Acirsa cf. corsicana*” (= *Acirsa subdecussata*) shell, 3.4 mm, Tuscan Archipelago (Italy), 400 m, from Smriglio et al. (1996), modified. Figs. 7–9: *Opalia coronata* juvenile shell, 2.7 mm, off Siracusa (Sicily, Italy), 50–75 m.

(Cantraine, 1835) by Franchini (1975) who deemed it as a mere juvenile specimen of the latter, apparently without a direct examination of the type. Smriglio et al. (1996) reported two shells found in bathyal sediments in Tuscan Archipelago and northern Corsica and illustrated one (Fig. 6), but refrained from conclusively ascribing this material to the species as lacking the distinctive punctuated sculpture. Later on, some authors simply depicted (Giannuzzi-Savelli et al., 1999) or drew (Repetto et al., 2005) the same shell under the name “*Acirsa corsicana*”, instead of “*Acirsa cf. corsicana*” as done by Smriglio et al. (1996). Other authors only cited *A. corsicana* without comments (Weil et al., 1999; Oliverio, 2008; Brown et al., 2015). Cossignani & Ardovalini (2011), without comments, depicted under the name *A. corsicana* two juvenile shells of *A. subdecussata*, asserting they are synonym. Currently, MolluscaBase (2020a) holds the aforementioned opinion.

Indeed *A. subdecussata* juveniles (Fig. 5) are quite distinct from *A. corsicana* specimen, having thinner shells with a more conical spire, often coeloconoid, and a subquadrate aperture. The glossy shell surface is devoid of intritacalx and shows more or less developed spiral grooves. The shell identified as “*Acirsa cf. corsicana*” by Smriglio et al. (1996) can be assigned to *Acirsa subdecussata*, as the absence of spiral sculpture, a feature also observed in other juvenile specimens of *A. subdecussata*, falls within the morphological variability of this species. On the other hand, the *A. corsicana* holotype, despite its imperfect state of preservation, can be assigned to *Opalia coronata* (Philippi et Scacchi, 1840), having the same spire outline, macrosculpture (number and form of axial ribs, crenulated suture) and microsculpture (spirally pitted intritacalx) (Figs. 7–9). *Acirsa corsicana* Nord-sieck, 1974 becomes accordingly a junior synonym of *Opalia coronata* (Philippi et Scacchi, 1840) (ICZN, 2012: Article 23).

After the description, *A. corsicana* holotype remained in the late Fulvio Giannini private collection that was later partially acquired (included that specimen) by the second author and incorporated in AP. According to ICZN, holotypes deposition in institutional repositories is not compulsory but recommended, in order to preserve and make them accessible for study (ICZN, 2012: Recommendation 16C). Following this recommendation *A. corsicana*

holotype will be deposited in MNHN with the following catalogue number: MNHN-IM-2000-35770.

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Community Structure of Road Associated Avifauna along the Urban Gradient in Mintal, Davao City, Southern Philippines

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ABSTRACT

The community structure of avifauna along the urbanization gradient in Mintal, Davao City was surveyed and analyzed. A total of 4,210 individuals from 34 species belonging to 23 families were recorded. Seven species are Philippine endemics and five are introduced species. Correlation and regression analysis showed a positive relationship between increasing vegetation cover with species richness and a negative relationship with abundance. Oppositely, increasing urbanization (increase built-up cover, pedestrian and traffic rate) were observed to have positive relationship to abundance but negative relationship to species richness. Thus, the avian community in the urbanization gradient of Mintal, Davao City follows the general accepted trend that in heavily disturbed areas, species richness is at its lowest while total bird abundance is at its peak. This study also suggests the importance of green spaces with lesser traffic rate in urban landscapes that could support higher avian diversity which includes Philippine endemic species.

KEY WORDS

Abundance; Birds Diversity; Species richness; Urbanization.

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INTRODUCTION

Birds are important environmental bioindicators because of their high sensitivity to anthropogenic disturbances, changes and stress in the habitat structure (Kale et al., 2012; Verma & Murmu, 2015). The species composition, population structure and diversity of an avian community, and even the abundance of one or more significant bird species, can be used to estimate the environmental quality of an area (Padoa-Schioppa et al., 2006). *Columba livia* Gmelin, 1789, for example, are known to be

dependent on urban environment (Shochat et al., 2006) and their presence in a particular area is an indicator that an environment is urbanized or somehow urbanized and developed.

Urbanization changes the avian community structure of a habitat (Blair, 1996; Chace & Walsh, 2006). Loss and reduction of natural habitat cause local extinction of native birds that are dependent on the native flora and vegetation, while species that are able to adapt and exploit the urbanized habitat survives (Er et al., 2005). This results in a large biomass and dominance of some bird species in

urban ecosystems but the species richness is reduced (Chace & Walsh, 2006).

While urbanization has generally a negative effect on biodiversity, some tolerant species may gain benefits from it (DeStefano & DeGraaf, 2003). For example, species of birds that nests on rocky cliffs and caves may find better nesting sites on walls of residential and commercial buildings (Rolando et al., 1997). It has also been observed that suburban habitats have the most diverse avian community (Verma & Murmu, 2015). Along the urban-rural gradient, in places where disturbance is at an intermediate level, species richness is typically expected to reach its peak than compared to the two extreme habitats (Blair, 1996; Connell, 1978; McKinney, 2002).

In relation to urbanization, construction of roads directly causes habitat loss, destruction, and fragmentation of existing ecosystems and local landscape (Coffin, 2007). Roads also has severe effects on avian populations such as increased mortality rate due to road collisions, and changes in ecological conditions such as alterations to light, moisture, hydrology, and background noises (Benítez-López et al., 2010; Coffin, 2007; van der Ree et al., 2011). However, roads are reported to attract some birds due to food availability, reduced predation pressures, and offers warm surface and street lights which helps conserve their metabolic energy (Morelli et al., 2014).

This study can provide lists of avian species which can tolerate or can be attracted by roads in an urban area, and underlines the importance of road characteristics that might affect its community structures. Currently, there are few studies conducted on the community of birds associated in urban roads in the country, by knowing the factors affecting the birds, this could provide significant contribution for the enhancement of wildlife conservation coupled with effective urban planning in an expanding urban area in Southern Philippines.

This study aims to determine the community structure of road associated avifauna and its relation to changing levels of disturbance along the urban gradient in the growing metropolis of Davao City. Specifically, this study aims: to characterize urban bird community structures in terms of richness, abundance and diversity, and to determine the relationship of urbanization variables with respect to avian abundance, richness and diversity.

MATERIAL AND METHODS

Study area

Mintal, located northwest of Metro Davao City, Philippines is an urban barangay which occupies a land area of 768.21 hectares accommodating a total population 13,227 according to the last 2015 Census (PSA, 2019). Mintal is a category 3 urban barangay defined as a barangay which has five or more establishments with a minimum of ten employees and has five or more facilities within the two-kilometer radius from the barangay hall (PSA, 2019).

Figure 1 shows a map of the study site in Mintal, Davao City (coordinates; 7.0887, 125.5075). It can be observed that the eastern portion of Mintal is highly urbanized where urban structures are heavily clustered and few vegetation is present. Urban facilities such as parks, public markets, department stores, hospital, fire station, and etc. are located in this area. It can also be observed that the urbanization level gradually decreases from east to west direction of Mintal, where urban structures and houses becoming less in number and less clustered, and vegetation gradually increasing in density and cover.

Avian survey methodology

Bird surveys were conducted between the months of December 2018 to April 2019. A total of 8 surveys for each transect lines, totaling 16 bird surveys (including both morning and afternoon surveys), were done.

Point transect method was used to survey the avian species richness and diversity in the area. In this method, observers traveled along the transect, which is situated along the roads, while stopping in predefined points and recording all birds that were seen and heard for a predetermined amount of time of five minutes. Two 3,600 m roads in Mintal that exhibits an urbanization gradient, shown in Figure 1, were selected as the transect sites with 19 sampling points in each transect following the suggested minimum distance of 200 m between each sampling points (Gregory et al., 2004).

Location of sampling points were predetermined by using Google Earth. The first sampling

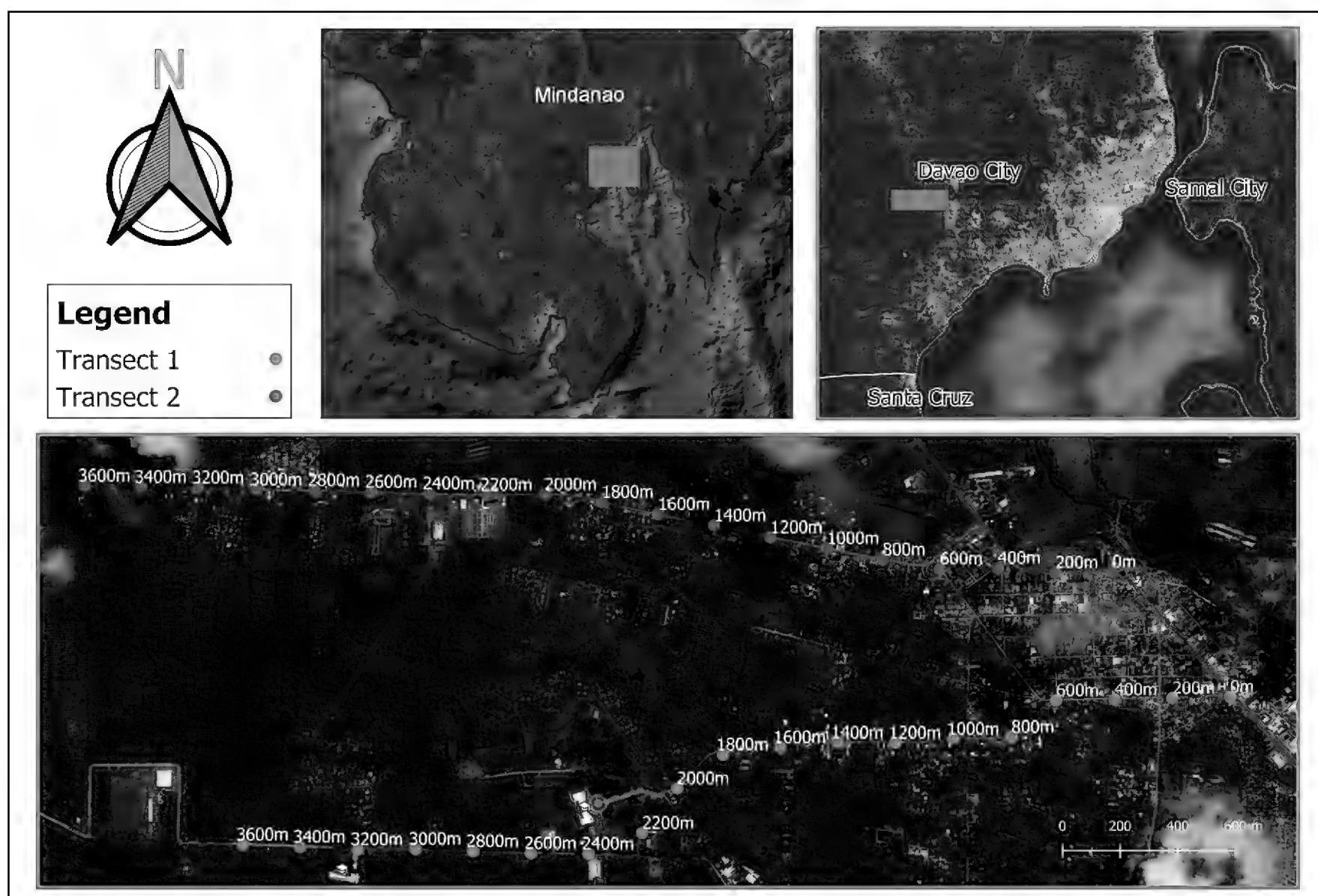


Figure 1. Map of the study site with the sampling points across two transect sites (modified from Google Earth, 2019).

point is in 0 m, using the distance measurement tool of Google Earth, the next sampling points, which are 200 m apart from each other, were located until the last point. Morning survey of birds were conducted 30 minutes after sunrise between 6:30AM – 8:00AM, and late afternoon surveys between 5:00PM – 6:00PM when bird activities are in its peak (Billy et al., 2000). Five-minute counts were conducted in each sampling points. All birds that were seen, with the help of binoculars, and heard within the estimated 30 m radius were recorded (Verma & Murmu, 2015). After 5 minutes in a sampling point, all activities were stopped and observers moved on to the next sampling point where the next observations were conducted. This was repeated until the last sampling point in a transect.

Bird surveys are commonly designed to start early in the morning when bird activity is highest until mid-morning when bird activity starts to decline (Billy et al., 2000; Gregory et al., 2004). This leads to bird encounters tending to be higher on sampling points sampled earlier than on sampling

points sampled later. The opposite effect could be expected for afternoon survey, since bird activity in the afternoon peaks at time before dawn (Billy et al., 2000). There is now a sampling bias based on time. Therefore, to eliminate the time bias in this study, transects that were revisited were surveyed starting from the other end of the transect going in the opposite direction of the first surveys (Billy et al., 2000).

Moreover, considering the 3,600 m length of each road transect, aside from time bias, an observation bias based on fatigue may also occur when surveying a very long transect. To address this concern in this study, instead of surveying the whole transect in one go, each transect sites were divided into two separate surveys instead. The first part of the transect starting from 0m to 2,000 m sampling points were sampled (including morning and afternoon surveys) on the first day while the remaining 2,200 m – 3,600 m sampling points were sampled on a different day. After a transect is sampled in the 0 m – 3,600 m direction, the succeeding surveys on a same transect were conducted after at least two

weeks have passed. Transect revisits were sampled by going in the opposite direction of the first surveys starting from the 3,600 m to 2,200 m sampling points on the first day and the remaining 2,000 m – 0 m sampling points were sampled on a next day.

Guide books “A Guide to the Birds of the Philippines” by Kennedy et al. (2000) and “A Naturalist's Guide to the Birds of the Philippines” by Tañedo et al. (2015) were used as field guide for confirming the identification of bird species in this study. The International Union for Conservation of Nature and other relevant publications were used as the basis for avian distribution and conservation status.

Environmental variables

Percent cover of vegetation, which covers all types of herbaceous, shrubby and/or arboreal vegetation, within the 30 m radius from each sampling points were estimated and recorded (Villegas & Zavala, 2010) by using a free image processing software ImageJ (Schneider et al., 2012). Built-up cover of urbanization density within the 30 m radius of each sampling point was also estimated and recorded (Villegas & Zavala, 2010). This includes buildings, houses, roads and any urban related structures. By using Google Earth, a map screenshot of the latest satellite image of each sampling points was imported. The imported images were processed using ImageJ (Schneider et al., 2012) to measure the percent cover of vegetation or built-up density around 30 m radius of the sampling point.

Pedestrians that passed by or in-standby within the 30 m radius within each sampling point during the bird surveys were recorded (Villegas & Zavala, 2010) by a different observer. Just like the pedestrian rate, any vehicle that passed by during the 5 minutes bird survey was recorded simultaneously (Villegas & Zavala, 2010). Pedestrian and vehicle rates were all recorded by a single observer. This includes all types of vehicles from motorcycles up to 6 to 8-wheeler utility vehicles. Bicycle are excluded for this variable and is recorded as a pedestrian instead since it does not generate noise and disturbance as much as vehicles.

Data analysis

Avian diversity of each sampling points across all transects were measured by using the Shannon-

Weiner Diversity Index. Moreover, to estimate the number of species in the sampling sites, Jackknife 1 rarefaction analysis was done. Pearson's correlation test was used to analyze the association of the distance from the urban core on avian abundance, richness, evenness and diversity. Moreover, the effects of environmental and disturbance variables (vegetation cover, urban density, pedestrian rate, and traffic rate) to avian abundance and species richness were measured and analyzed using simple linear regression analysis.

RESULTS AND DISCUSSION

Community structure of urban birds

A total 4,210 individuals of birds belonging to 34 bird species from 23 different families were recorded and identified. Seven species were identified as Philippine endemics namely: *Phapitreron brevirostris* Tweeddale, 1877, *Dicaeum australe* (Hermann, 1783), *Copsychus mindanensis* (Boddaert, 1783), *Arachnothera flammifera* Tweeddale, 1878, *Bolbopsittacus lunulatus* (Scopoli, 1786), *Loriculus philippensis* (Müller, 1776), and *Rhipidura nigritorquis* Vigors, 1831. Five are identified as introduced species: *Acridotheres cristatellus* (Linnaeus, 1766), *Passer montanus* (Linnaeus, 1758), *Geopelia striata* (Linnaeus, 1766), *Lonchura oryzivora* (Linnaeus, 1758) *Columba livia* Gmelin, 1789 (Gonzalez, 2006). Moreover, almost all species recorded during the study are of Least Concern except for *Lonchura oryzivora* or Java Sparrow which is categorized as Vulnerable by the International Union for the Conservation of Nature (IUCN, 2019).

Jackknife 1 rarefaction analysis (Fig. 2) showed an estimate of 38 species that can be found in Mintal, Davao City. This means that 89.47% of the estimated total species were observed during the study, predicting that more species could be present in the area than the actual species count. Species richness is expected to reach its peak in areas where disturbance is still in intermediate level due to changes in landscapes resulting to habitat diversity and heterogeneity (Blair, 1996; Connell, 1978; McKinney, 2002). The area exhibits a mosaic of different habitat types as seen in the map (Fig. 1) which may be the reason for the high species count.

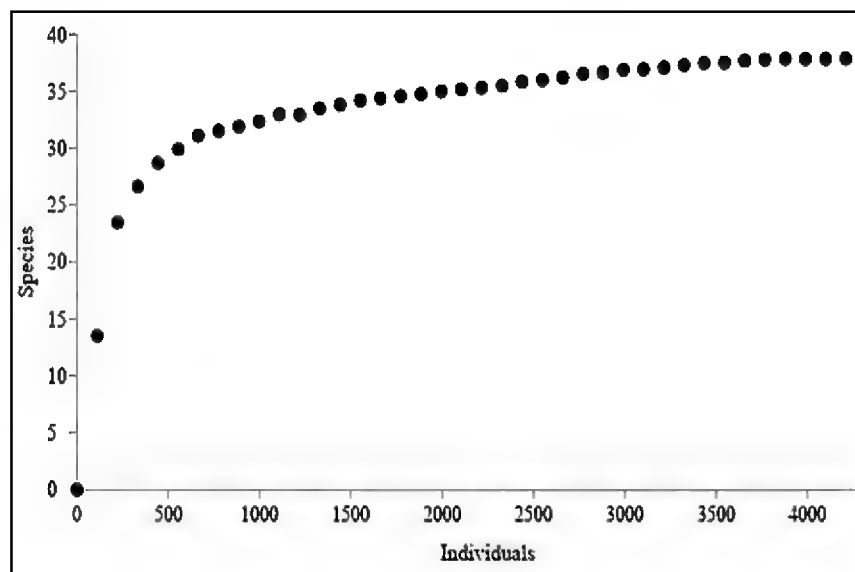


Figure 2. Jackknife 1 individual-based rarefaction curve of avian species which shows a total of 38 estimated species that can be found in Mintal, Davao City.

In terms of the diversity, Shannon-Weiner's Index of Diversity (2.435) showed lower value when compared to the calculated maximum diversity (3.526). Considering the high species count of 34, the low diversity index measured in Mintal can be attributed by the low value of species evenness (0.3358) and high abundance of some few species detected. Out of 4,210 individuals of birds recorded in the area, only six species contribute to about 75.9% of the total avian population. These species are: *Passer montanus*, *Aplonis panayensis* (Scopoli, 1783), *Pycnonotus goiavier* (Scopoli, 1786), *Cinnyris jugularis* (Linnaeus, 1766), *Columba livia*, and *Dicaeum australe*. The *P. montanus* in particular solely contributes to about 30% of the total abundance (Fig. 3).

Passer montanus is the most successful introduced species of birds in the Philippines being widely spread and found in nearly every human inhabited island in the country (Gonzalez, 2006; Kennedy et al., 2000). *Columba livia* on the other hand is one of the most common bird that can be found on heavily urbanized areas such as on business districts of cities (Kark et al., 2007; Tryjanowski et al., 2015). These two species are predominantly granivores, foraging on any seeds which can be found on the ground and can also feed on insects when necessary (Kennedy et al., 2000). Moreover, *P. montanus* and *C. livia* are known scavengers and will feed on any food left or thrown by humans in urban areas. These two species are heavily associated to human settlements and activities and are considered as bio-indicators of disturbance and urbanization (Gonzalez, 2006; Shochat et al., 2006).

Resources in disturbed and urbanized areas are limited due to urbanization and its structures (Chace & Walsh, 2006). Natural habitat types are destroyed and replaced by urban structures such as roads, buildings, and houses while native flora is either removed or displaced by garden plants and introduced flora (Chace & Walsh, 2006). A lot of species are dependent on such resources and incapable of adapting to urban pressures, and are forced to relocate to adjacent areas where resources are still available. This causes significant reduction and/or extirpation of several species' populations in highly urbanized and disturbed environments. Consequently, some species are able to adapt and utilize urban resources making their population persist on urban environments while a very few species have become very dependent on urban resources making their population completely dominating the urban communities (Shanahan et al., 2014).

Community changes along the urbanization gradient

Correlation analysis showed an increase in community diversity when going towards the less disturbed end of the urban gradient, showing a positive linear relationship ($r=0.685$) between the two parameters. Having less species means that there are less enemies to compete for an abundant urban food resource which causes very high density of very few species of birds in highly urbanized ecosystems (Shochat et al., 2010). As observed, there was an increasing trend in the number of species from the urban core ($r=0.4884$). According to Chace & Walsh (2006), urbanization tend to select for birds that are generalists, granivorous, aerial insectivores and cavity nesting species which results to lower species richness in urban avian communities dominated by few species which are often introduced. The highest bird density and abundance, *P. montanus*, *C. livia* and *A. panayensis*, was recorded on the sampling points or closest to the urban core. Notice that two of these species, *P. montanus* and *C. livia*, are introduced and granivorous species and the other one, *A. panayensis*, is an efficient generalist (Kennedy et al., 2000). These species also generally decrease in their abundance along the gradient.

Another possible reason for the low species richness in the urban core is biotic homogenization.

During homogenization, local flora will be replaced by the same introduced ornamental plant species (McKinney, 2006). This limits the survival of species of birds that are dependent on native flora for nesting and feeding. Several studies on the relationship between urban avifauna and flora already found evidence of positive correlation between native flora with native avifauna, and the positive correlation between introduced ornamental flora with introduced avifauna (Daniels & Kirk-Patrick, 2006; Emlen, 1974; Mills et al., 1989). This means that in urban areas where vegetation is very low, and if present it is mostly composed of exotic ornamental plants, only species who can utilize introduced resources have the ability to thrive, which are also mostly generalist and introduced species.

Effect of environmental variables to species richness and abundance

Among the environmental variables tested in this study, the highest regression value (R^2) for species richness (0.4046) and bird abundance

(0.65343) was the traffic rate, suggesting that traffic could be the main factor that affects avian abundance and richness in the area (Tables 1, 2). Traffic is the primary source of noise pollution in urban environments. Noise pollution from cars as well as some urban sources can mask acoustic signals made by birds (Barber et al., 2010; Gil & Brumm, 2014; van der Ree et al., 2011). Signals such as mating calls and warning calls will be poorly perceived by birds which can cause for them incapability to reproduce or vulnerability to predators (Gil & Brumm, 2014). Several studies have already found evidence of species in urban areas that have adapted to the noise pollution by altering the amplitude, frequency, duration, and timing of their calls (Bergen & Abs, 1997; Brumm & Zollinger, 2011; Parris & Schneider, 2009; Schuster et al., 2012; Verzijden et al., 2010; Wood & Yezerinac, 2006). Increase in car and traffic density in the area is a direct effect of urbanization and disturbance in the area. Therefore, urbanization is still the main force that affects the avian community's species richness and abundance.

In contrast, the lowest measured R^2 value for

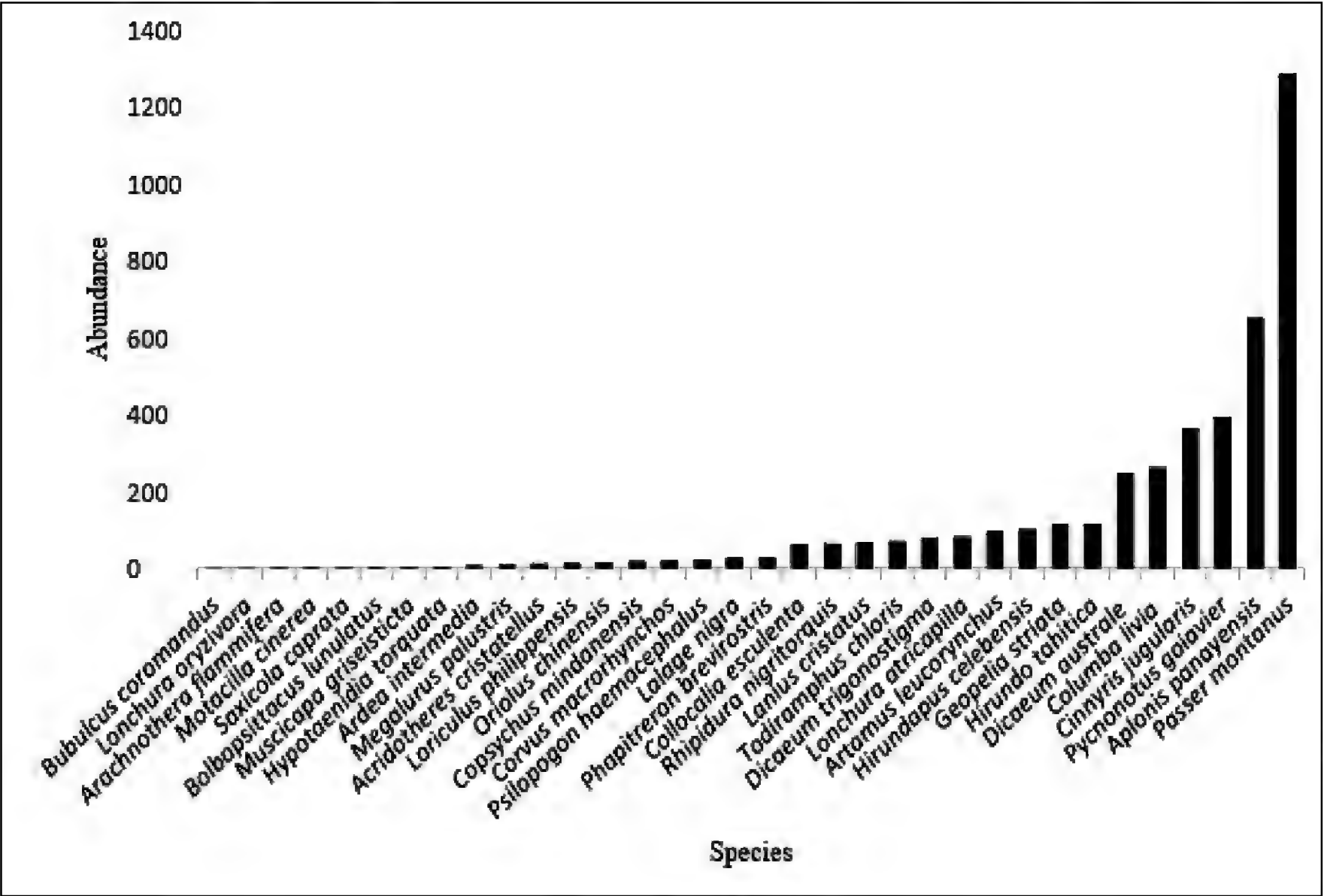


Figure. 3. Abundances of the avian species recorded in Mintal, Davao City.

both species richness (0.17398) and abundance (0.23765) was from pedestrian rate. The measured R^2 values indicates that there is a weak linear relationship between species richness or abundance of birds to increasing pedestrian rate in Mintal. In urban areas, birds typically are less sensitive and can tolerate human presence better than in rural areas and natural areas (Rander, 2008). However, according to Clucas & Marzluff (2012), habituation of birds to human presence may differ between different places. In their study, they discovered that discouraging behavior of humans towards birds made birds warier to human presence. Nevertheless, human presence still generally affects birds in urban areas especially when nearby feeding or nesting areas. Increased urbanization, which is correlated with increased human visitation and disturbance, causes decreased reproductive success on birds through desertion of eggs, decreased hatching success, decreased ability to feed young, and decreased parental attendance (Chase & Walsh, 2006).

Aside from car density and traffic rate, the urban structures and vegetation cover variables almost have the same values of R^2 measured for species richness (urban density=0.30048, vegetation cover=0.31991) and abundance (urban density=0.46722, vegetation cover=0.46406). This is because the loss of vegetation is directly caused by increasing urbanization. Urbanization directly causes loss, destruction and fragmentation of natural habitats (Chace & Walsh, 2006; Fuller et al., 2010;

Shanahan et al., 2014) which means that the amount of urban structures and urbanization in an area could be affected by the lost and displaced vegetation and natural habitat. The amount of urban structures and vegetation cover have the exact opposite effects to a community's species richness and abundance. Bird abundance is very high in highly urbanized areas while species richness is in its lowest however, as urbanization decreases and vegetation increases, species richness of the community increases while total abundance of birds decreases (Chace & Walsh, 2006; Seress & Liker, 2015).

CONCLUSIONS

Avian community in the urbanization gradient of Mintal, Davao City follows the general accepted trend that in heavily disturbed areas, species richness is at its lowest while total bird abundance is at its peak. However, our result strengthens the fact that in an urban environment, green spaces and lesser traffic positively support avian diversity which includes the Philippine endemic species. This highlights the need to support the existence of urban green spaces with high vegetation complexity during urban planning. Though the result of this study observed the possible urban factors that pressures avian richness and diversity in a changing urban gradient, the various responses of different birds' species in urban environment need further understanding.

Variables	Species Richness			Abundance		
	coefficient	R^2	<i>P-value</i>	coefficient	R^2	<i>P-value</i>
Vegetation cover	0.0889	0.31991	0.00022	-1.5687	0.46406	2.51E-06
Urban structures	-0.0836	0.30048	0.00037	1.5276	0.46722	2.25E-06
Traffic Rate	-0.0153	0.4046	1.77E-05	0.2855	0.65343	8.39E-10
Pedestrian Rate	-0.0967	0.17398	0.00918	1.6565	0.23765	0.00191

Table 1. Individual Linear Regression Analysis Values between species richness and abundance with Different Environmental Variables.

Scientific Name	Common Name	Abundance	Relative Abundance
<i>Bubulcus coromandus</i> (Boddaert, 1783)	Eastern Cattle Egret	1	0.00023753
<i>Lonchura oryzivora</i> (Linnaeus, 1758)	Java sparrow	1	0.00023753
<i>Arachnothera flammifera</i> Tweeddale, 1878	Orange-tufted Spiderhunter	2	0.000475059
<i>Motacilla cinerea</i> Tunstall, 1771	Grey Wagtail	2	0.000475059
<i>Saxicola caprata</i> (Linnaeus, 1766)	Pied Bush Chat	2	0.000475059
<i>Bolbopsittacus lunulatus</i> (Scopoli, 1786)	Guaiabero	3	0.000712589
<i>Muscicapa griseisticta</i> (Swinhoe, 1861)	Grey-streaked Flycatcher	3	0.000712589
<i>Hypotaenidia torquata</i> (Linnaeus, 1766)	Barred Rail	4	0.000950119
<i>Ardea intermedia</i> Wagler, 1829	Intermediate Egret	6	0.001425178
<i>Megalurus palustris</i> Horsfield, 1821	Striated Grassbird	10	0.002375297
<i>Acridotheres cristatellus</i> (Linnaeus, 1766)	Crested Myna	11	0.002612827
<i>Loriculus philippensis</i> (Müller, 1776)	Philippine Hanging Parrot/Colasisi	12	0.002850356
<i>Oriolus chinensis</i> Linnaeus, 1766	Black-naped Oriole	13	0.003087886
<i>Copsychus mindanensis</i> (Boddaert, 1783)	Philippine Magpie Robin	17	0.004038005
<i>Corvus macrorhynchos</i> Wagler, 1827	Large-billed Crow	18	0.004275534
<i>Psilopogon haemacephalus</i> (Müller, 1776)	Coppersmith Barbet	22	0.005225653
<i>Lalage nigra</i> (Forster, 1781)	Pied Triller	26	0.006175772
<i>Phapitreron brevirostris</i> Tweeddale, 1877	Short-billed Brown Dove	26	0.006175772
<i>Collocalia esculenta</i> (Linnaeus, 1758)	Glossy Swiftlet	60	0.014251781
<i>Rhipidura nigritorquis</i> Vigors, 1831	Philippine Pied Fantail	63	0.014964371
<i>Lanius cristatus</i> Linnaeus, 1758	Brown Shrike	65	0.01543943
<i>Todiramphus chloris</i> (Boddaert, 1783)	Collared Kingfisher	69	0.016389549
<i>Dicaeum trigonostigma</i> (Scopoli, 1786)	Orange-bellied Flowerpecker	77	0.018289786
<i>Lonchura atricapilla</i> (Vieillot, 1807)	Chesnut Munia	81	0.019239905
<i>Artamus leucorhynchus</i> (Linnaeus, 1771)	White-breasted Woodswallow	94	0.022327791
<i>Hirundapus celebensis</i> (Sclater, 1865)	Purple Needletail	100	0.023752969
<i>Geopelia striata</i> (Linnaeus, 1766)	Zebra Dove	112	0.026603325
<i>Hirundo tahitica</i> Gmelin, 1789	Pacific Swallow	114	0.027078385
<i>Dicaeum australe</i> (Hermann, 1783)	Red-keeled Flowerpecker	246	0.058432304
<i>Columba livia</i> Gmelin, 1789	Rock Dove	261	0.061995249
<i>Cinnyris jugularis</i> (Linnaeus, 1766)	Olive-backed Sunbird	362	0.085985748
<i>Pycnonotus goiavier</i> (Scopoli, 1786)	Yellow-vented bulbul	393	0.093349169
<i>Aplonis panayensis</i> (Scopoli, 1783)	Asian Glossy Starling	650	0.154394299
<i>Passer montanus</i> (Linnaeus, 1758)	Eurasian Tree Sparrow	1284	0.304988124
Total		4210	1

Table 2. Abundance and Relative Abundance of All Avian Species in Mintal, Davao City.

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On the footsteps of Théodore Monod: biogeographical and ecological implications of an insect assemblage from the hottest spot on earth (in central Lut Desert, SE Iran)

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ABSTRACT

We present the entomological results of a geological and biological exploration in the Lut desert, performed in 2014 by the Iranian National Institute for Oceanography and Atmospheric Sciences (INIOAS) and the University of Tehran. Five localities were sampled, including the one considered as the the hottest spot on Earth. They yielded 15 insect taxa belonging to Blattodea, Orthoptera, Coleoptera, Heteroptera, suggesting that in spite of being originally described as “abiotic” or “aphytic”, the Lut desert shelters a diverse insect fauna with some remarkable elements such as the endemic desert cockroache *Leiopteroblatta monodi*. Comparison with results obtained by Franco-Iranian expeditions in the sixties and seventies reveals several taxa in common, but also striking differences in the composition of the insect assemblages, suggesting that the insect fauna in the Lut desert is potentially much more diverse than previously expected.

KEY WORDS

Lut insect fauna; aphytic; abiotic; Irano-Turanian; Saharo-Sindian.

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INTRODUCTION

The Lut Desert (also “Lout” and “Loute”) in Southeast Iran is one of the most hostile places on Planet Earth. It has been registered as World Heritage site in 2016 meeting criteria VII and VIII displaying exceptional natural beauty and unique geological and biological features (<https://whc.unesco.org/en/list/1505/>). Its southern extremity has been suggested as the hottest spot on Earth (Mildrexler et al., 2006, 2011; Stone, 2016; Azarderakhsh et al., 2020).

Théodore Monod in his famous book “Les Déserts” (1973) states that he has measured sand temperatures of up to 55°C in February and suggests the possibility of summer temperatures rising

Théodore Monod in his famous book “Les Déserts” (1973) states that he has measured sand temperatures of up to 55°C in February and suggests the possibility of summer temperatures rising

up to about 80°C! Such extremely high temperatures have recently been confirmed by instrumental measurements which reveal 61 °C temperature in July 2014 (Pourkhorsandi et al., 2019). Most of the Lut Desert has been described as “abiotic” or at least “aphytic” due to the near absence of any visible sort of life (Dresch, 1968; Monod, 1973; Mobayen, 1976).

Even if the “azoic” or “abiotic” nature of the central Lut (Dresch, 1968; Monod, 1973) has recently been questioned by several adventurers who have observed some animal life, the almost aphytic nature (Mobayen, 1976) of this area especially in Kalut and Central Hammada is almost evident.

Austrian adventurers and geographers A. Gabriel and G. Stratil-Sauer are the first western scientists who have traversed the Lut Desert and have given detailed account on their physical and biological observations of the desert (Gabriel, 1938; Stratil-Sauer, 1956). However, the first systematic study on the geomorphology and ecology of Lut was performed in the framework of several Franco-Iranian joint missions in the late 1960’s and early 1970’s and resulted in a number of short papers and reports (e.g., Dresch, 1968; Pierre, 1969, 1970, 1974). In 2014, two scientific expeditions with geological and geomorphological objectives were organized by Iranian National Institute for Oceanography and Atmospheric Sciences (IN-IOAS) and the University of Tehran (March and April 2014). Although the central parts of the desert were found almost totally “aphytic”, the visitors (M. Djamali, H. Pourkhorsandi) encountered a remarkable diversity of insects especially during the second field excursion (16–20 April 2014) and took this opportunity to sample this fauna.

This study reports the identified arthropod samples collected during these expeditions. It also provides a short description on the ecological context in which these insect assemblages were collected and the biogeographical implications inferred from their presence.

PHYSICAL AND BIOGEOGRAPHICAL SETTING

Geomorphology

Lut (Dasht-e Lut) is an approximately 80,000

km² desertic territory located in southeastern Iran (Fig. 1). Geologically, it forms a rigid block called “Lut Block” separated from its adjacent tectono-sedimentary units by complex fault systems especially in the East and West (Stocklin, 1968). Geomorphologically, it contains a variety of landforms of very different dimensions that can be simplified as the following units:

(i) Kalut. Kalut represent a complex system of NWN-SES directed parallel valleys and crests formed due to strong aeolian erosion over a long but unknown geological time. Their formation is mostly due to wind erosion, the wind abrasion being 3 to 4 times stronger in the valleys (grooves) than over the crests (Ghodsi, 2017). They cover an area of ~70 x ~120 km in western Lut (Fig. 1). Kalut are sometimes referred to as “yardangs” (e.g., Ghodsi, 2017).

If the use of this term is accepted, they represent most probably the highest yardangs on Earth (Dresch, 1968). Kalut seem to be of the same geological composition as Central Hammada (see below) but having undergone a deep fluvio-aeolian erosion during the Neogene.

(ii) Central Hammada. This geomorphological unit essentially occupies the central and northwestern part of Lut (Fig. 1). Although Kalut also seem to be almost deprived of animal and plant life unless in their marginal zone, the specific “abiotic” zone of Lut is often used to describe this part of the desert (Mobayen, 1976). Central Hammada are not totally flat but show a complex drainage pattern, terraced surfaces; small and large polygonal structures formed due to the growth of evaporates in soil and many other geomorphological features.

Strong deflation seems to have contributed in the formation of several endorheic depressions such as “Hamoun-e Shūrgaz” (Fig. 1).

(iii) Rig-e Yalan Erg. This is a huge erg (sand sea) covering an area of ~65 x 130 km located in eastern Lut. Due to exceptionally high elevations of huge sand dunes of this desert (up to > 400 m according to unpublished sources) especially in its central parts, some scholars have referred them as “dune massifs” (Mobayen, 1976). Barkhans and star dunes occupy smaller territories compared to Rig-e Yalan and are especially found bordering the latter.

Bioclimatology

Iran displays a wide variety of bioclimates rang-

ing from “temperate oceanic” bioclimate in south Caspian region, “Mediterranean” bioclimates over the central Iranian plateaus and mountain ranges and “tropical arid/hyperarid” bioclimates in the south and southeast (Djamali et al., 2011). In this

broad spectrum of bioclimates, the driest and hottest bioclimate, i.e., the “tropical hyperarid” is found in the Lut Desert (Fig. 2). It is characterized by a long dry season ($P < 2T$) lasting all the year. Only one meteorological station was found to be close

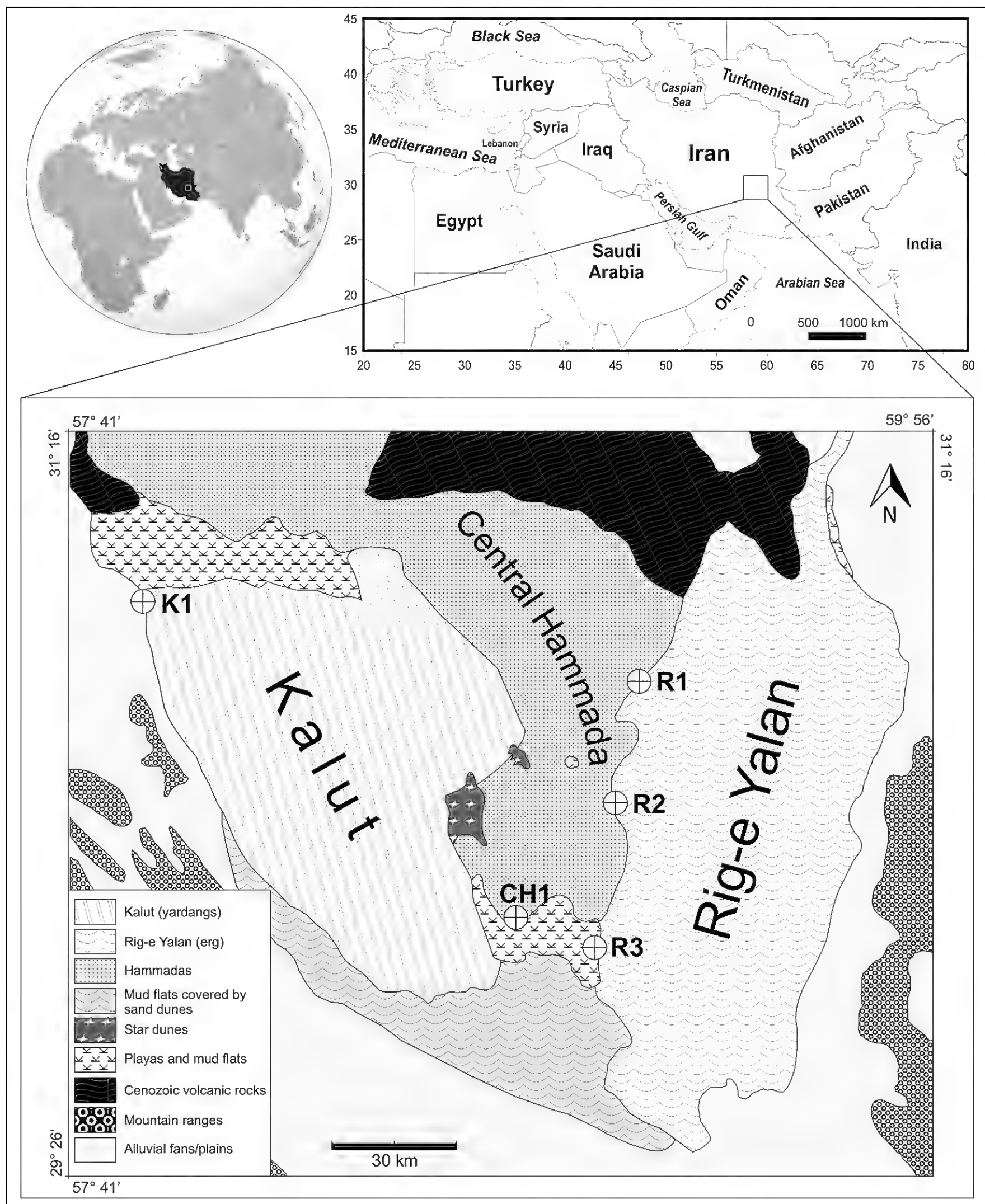


Figure 1. Lut desert and location of the sampling sites.

enough to central Lut to give a general estimation of the harsh climatic conditions of Lut (see climate diagram in figure 2). Over a 13-year long meteorological record (1986–2003), the average of maxima of the hottest month have been measured as 47.5°C

while the hottest absolute temperature ever measured has been about 55°C (July 1995). The mean annual precipitation has been as low as 28 mm. One could easily imagine a still higher temperatures and lower precipitations in central Lut Desert especially

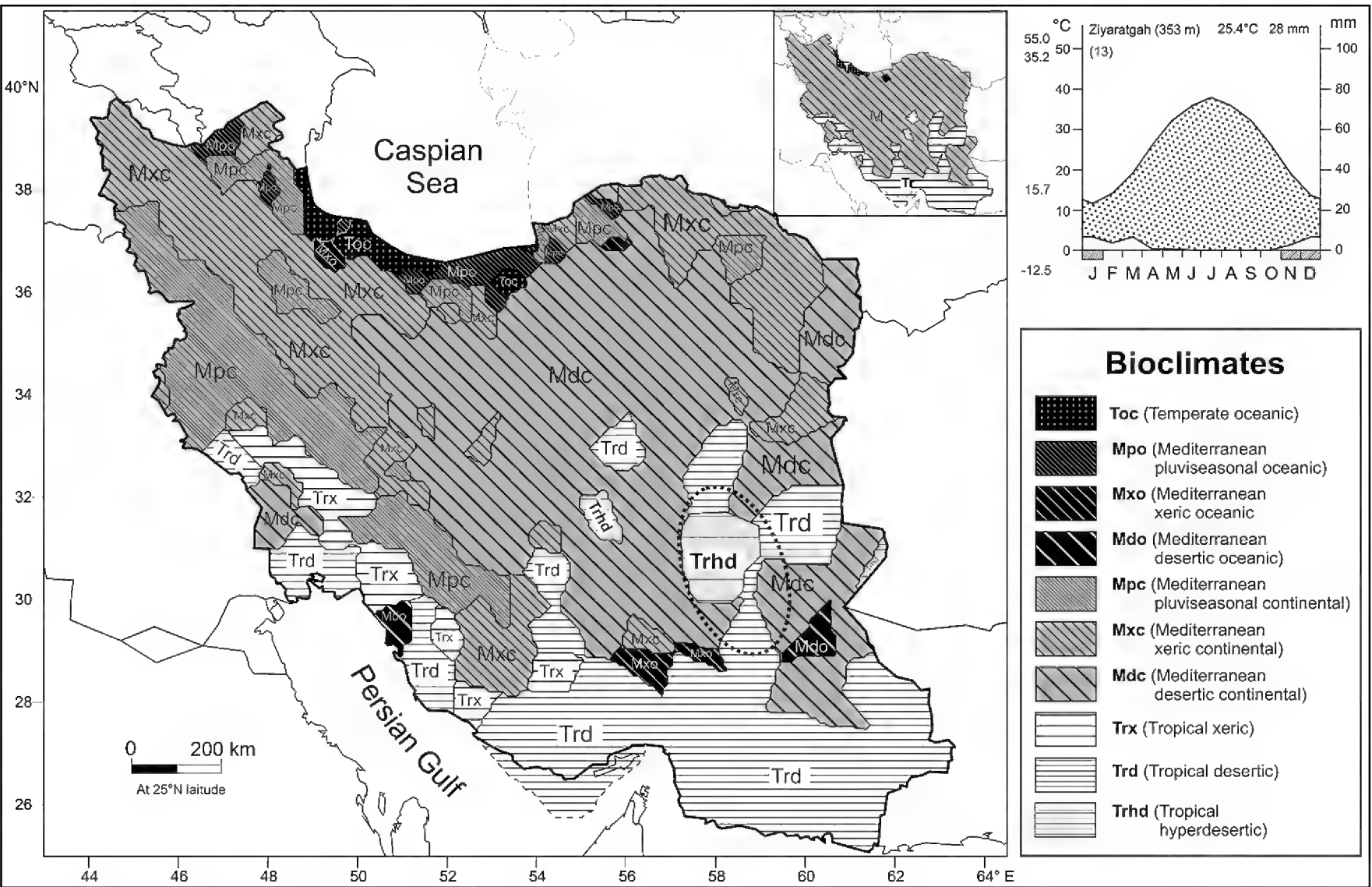


Figure 2. Bioclimates of Iran, Lut desert in the dotted circle.

Site	Coordinates			Date	Time (Hour)	Description
	Lat. (N)	Long. (E)	Alt. (m)			
K1	30°47'19.35"	57°47'6.04"	306	30/03/2014	22	Kalut : NWN-SES directed valley floor bordered by 40 m high hills. Valley floor is covered by coarse aeolian sands.
R1	30°36'6.09"	59°11'37.48"	596	29/03/2014	09	Rig-e Yalan: Sand dunes in NW of Rig-e Yalan at the very proximity of Central Hamadas
R2	30°18'19.26"	59° 7'48.51"	511	20/04/2014	21	Rig-e Yalan/Central Hamadas transition: A hamada bordered and partly covered by sand dunes.
R3	29°57'26.79"	59° 4'15.45"	292	19/04/2014	21	Rig-e Yalan: Sand dunes in SE of Rig-e Yalan at the proximity of Central Hamadas; supposedly the hottest spot on Earth (Midrexler et al., 2009).
CH1	30° 4'22.63"	58°55'22.65"	285	18/04/2014	21	Central Hamadas: Isolated outcrops of Kalouts in the Central Hamadas. Beetles were collected inside and besides salty spring bordered with a band of a monospecific <i>Tamarix</i> stand.

Table 1. Sampling sites.

in the supposedly “hottest spot on Earth” (Mildrexler et al., 2006, 2011). A Thermometer installed in near standard conditions of meteorological stations in 2014, recorded 61 °C in July 2014 suggesting that the soil temperatures exceeding 70 °C are quite possible (Pourkhorsandi et al., 2019).

Biogeography

The delineation of the phytogeographical limits of the Saharo-Sindian and Irano-Turanian regions at Lut Desert is not still well defined (Djamali et al., 2011, 2012). Léonard (1981-1989, 1991/1992) describes the Lut Desert as belonging to the Irano-Turanian floristic region. However, unlike the more north-central Iranian deserts, less than half of the species found in the periphery of this desert belong to the Irano-Turanian endemic species and there is a considerable percentage of plants belonging to other regions. This makes Léonard to define the Lut as a “Local zone of endemic impoverishment” within the “Irano-Turanian regional zone of endemism” (Léonard, 1993). Indeed, 35.6% of the Lut elements belong to the Irano Turanian region while 16.8% to the Saharo-Sindian region, 7.6% to Nubo-Sindian, 4.2% to Somalia-Massai, 0.7% to Indian regions and the rest of the elements are the linking species simultaneously found in several regions. The psamophilous beetle fauna of Lut also shows many similarities with north-western Saharan elements at the genus level confirming the strong zoogeographical imprint of Saharo-Sindian fauna on the Lut fauna (Pierre, 1974).

MATERIAL AND METHODS

During our two expeditions to central Lut, we did not observe any sign of plant life in Kalut and Central Hammada with the exception of a very small stand of *Tamarix* in CH1 site (see below) and presence of very sparse psammophytes (*Caligonum* spp. and *Cyperus* spp. and Brassicaceae) in the interior parts of Rig-e Yalan. However, we were surprised by the high abundance of insect fauna. The predominant insect groups encountered were beetles, bugs, grasshoppers, moths, and a species of wind spider (not treated in this study). Blattodea, Orthoptera, Coleoptera Carabidae and Coccinellidae were studied by P. Ponel;

Coleoptera Hydraenidae by M. Jäch; Coleoptera Elateridae by G. Platia; Coleoptera Scarabaeidae by D. Keith; Coleoptera Aphodiidae by P. Bordat; Heteroptera by P. Magnien and A. Matocq; the insect material collected is preserved in their respective collections.

Table 1 summarizes the description of the five stations from which insects were collected. A more detailed description of each locality is given here: K1. This site is located in the northwestern corner of the Kalut formation in the floor of a NWN-SES directed valley bordered by ~40 m high crests (Fig. 3). The valley floor is covered by coarse aeolian sands. K1 is located at only 1400 m to the Shahdad to Nehbandan road and the nearest habitations are located at about 25 km to the south. A halogen light was also installed in the camp site to attract insects at night.

R1. This station was located at the northwestern limit of Rig-e Yalan, inside the sand dunes (Fig. 4).

R2. Situated at the transitional zone between Rig-e Yalan erg and Central Hammada, the R2 collection site was a relatively vast hamada surface bordered by low to medium-sized (<50 m high) sand dunes.

R3. This station (Fig. 6) is probably the most interesting collection site because it represents one of the supposedly hottest spots on Earth according to Mildrexler et al. (2006, 2011). Air temperatures at our arrival time (21:30 p.m. on 20/04/2014) were around 36°C. They increased to about 50° at 10:30 a.m in 21/04/2014. A data logger was installed in this site to record temperature and relative humidity over a year. The results are reported in Pourkhorsandi et al. (2019).

CH1. In the southwestern corner of the Central Hammada, the topographic difference between the surface of hamada and a vast depression covered with extensive mud flats and playas (“Hamoun-e Shūrgaz”) has caused the development of relatively deep gullies draining into the depression. A permanent spring with low discharge has emerged in one of these gullies harboring a remarkable small oasis-like ecosystem dominated by a healthy population of *Tamarix* sp. grown along the stream (Fig. 5). A water sample from the spring in CH1 was taken for measuring its chemical characteristics. Measurement of this sample in INIOAS analytical chemistry lab, gave a pH of 7.683, an EC of 53.1 mS/cm, and a salinity of 35.2 ppt at 28.7°C.

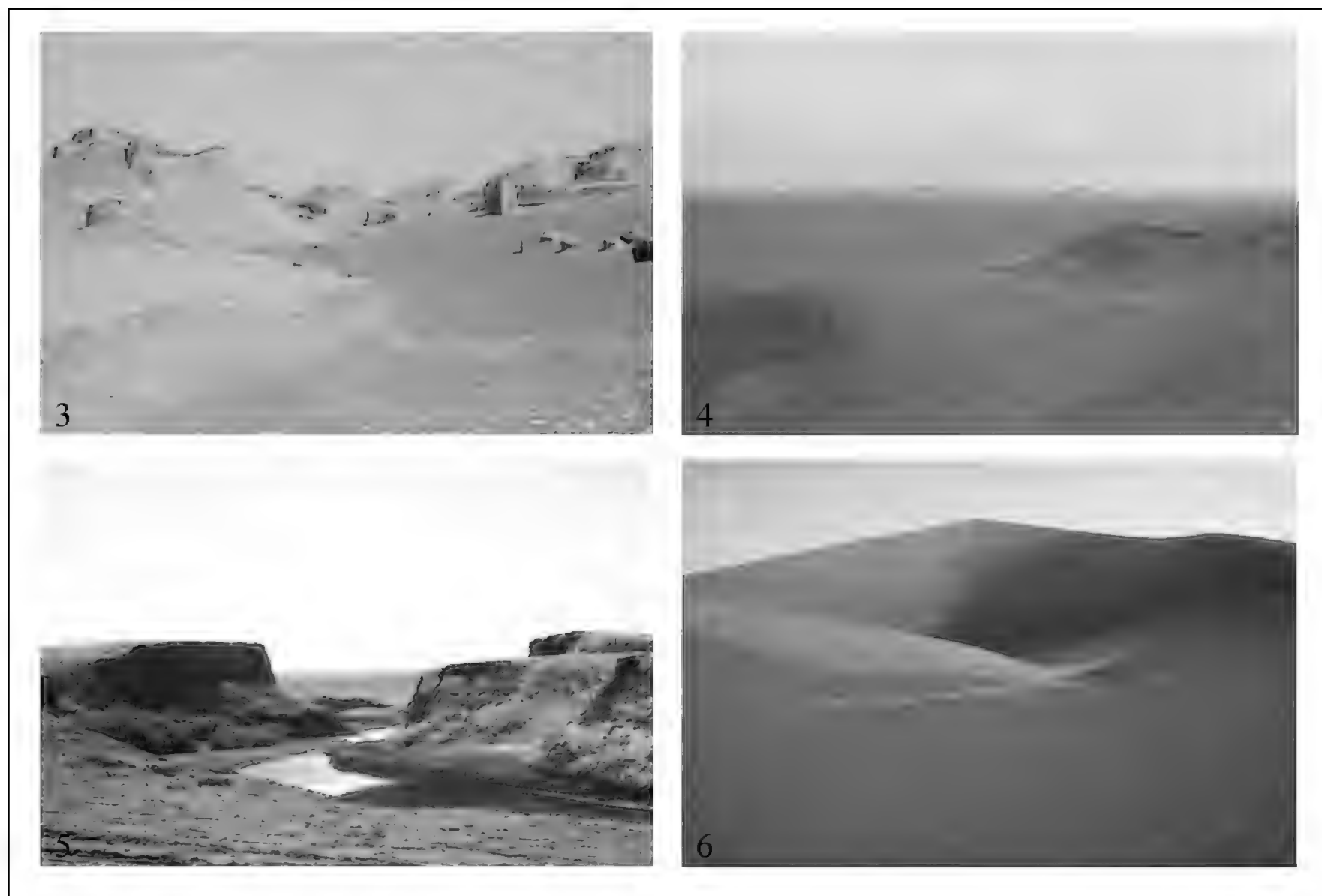


Figure 3. K1 site in northwestern border of Kalut. Figure 4. R1 site at the limit of the Rig-e Yalan and Central Hammada. Figure 5. CH1 site, Cheshmeh Shūrgaz in the transition between Kalut and the playas located in the south of Central Hammada. Figure 6. R3 site located in the supposedly hottest zone on Earth.

RESULTS

Ordo BLATTODEA Wattenwyl, 1882
Familia CORYDIIDAE Saussure, 1864

Leiopteroblatta monodi Chopard, 1969

One sand swimming cockroach specimen was collected in station R1 in the evening an hour after the sunset. This specimen corresponds to *Leiopteroblatta monodi*, an endemic species from the Lut desert, collected by Monod then described by Chopard (1969) and reported by Pierre (1970). As in most desert dweller cockroaches the body of *L. monodi* is covered with dense erected hairs creating a microclimate and protecting the animal from heat and dessication (Bell et al., 2007).

Ordo ORTHOPTERA Latreille, 1793
Familia ACRIDIDAE MacLeay, 1819

Sphingonotus sp.

Huge quantities of this grasshopper were observed in stations R2, R3, and CH1. In station CH1 we estimate the number of individuals of the grasshoppers as 10/m².

During the 1969 field trip, *Sphingonotus* (*Sphingonotus*) *theodori iranicus* (Mistshenko, 1936) was the only *Sphingonotus* species collected by the Franco-Iranian expedition in Lut desert, and it is possible that our grasshopper corresponds to the same species.

Ordo COLEOPTERA Linnaeus, 1758
Familia CARABIDAE Latreille, 1802

Megacephala (Grammognatha) euphratica Dejean, 1822

In station CH1 one specimen was collected at light near the halogen lamp. This is a widespread

species, distributed from southern Spain and North Africa to Iran and Oman, and the only member of the genus in the Palaearctic region (Puchkov & Matalin, 2003). This Tiger-beetle is a nocturnal predatory species, frequently attracted by light, and lives in flat regions of salt-encrusted desert near to permanent water (Gillett, 1995).

***Calosoma (Caminara) olivieri* Dejean, 1831**

In station R3 three specimens were collected at night near the halogen light. This is also a widespread predatory species, occurring from the Atlantic archipelagos (Azores, Canary, Cabo Verde) to India through North Africa. As noted by Jeannel (1940), it can live in humid climates in the West of its distribution (Atlantic Morocco, Atlantic archipelagos) but is restricted to semi-desertic and desertic climates to the East.

***Syntomus fuscomaculatus* (Motschulsky, 1844)**

One specimen was collected in station R3. This is another ground beetle with a very wide distribution area, found in most of the southern countries of the West Palaearctic, reaching the Oriental region (Kabak, 2003). The life habits of this species and that of other *Syntomus* is poorly known but they are usually found in open environments and dry habitats.

Familia HYDRAENIDAE Mulsant, 1844

***Ochthebius* spp.**

In station CH1, 4 specimens were collected from inside the stream. Three of the specimens seem to belong to *Ochthebius andraei* Breit 1920. Jäch (1992) synonymized *andraei* and *longitarsis* by Ferro 1982, which was described from SE Iran. However, there are slight differences between the type material of *andraei* (from Iraq) and the specimens recently collected from Lut. So maybe *O. longitarsis* could be in fact the true species, but at the moment the problem cannot be solved because it is necessary to collect and study more materials from different localities and populations. Another specimen from station CH1 is an immature female, which belongs to another species, but cannot be identified in the absence of males.

Familia ELATERIDAE Leach, 1815

***Aeoloides grisescens* (Germar, 1844)**

One specimen was collected at light in station K1. This click-beetle of the tribe Oophorini is a species widely distributed in Europe, North Africa and Asia, in the desertic and subdesertic areas of the Palaearctic and Afrotropical regions (Cate, 2007; Platia, 2007, 2011). In Saudi Arabia, *Aeoloides grisescens* was collected under canopies of *Acacia ehrenbergiana*, *Lycium shawii*, *Rhazya stricta* and *Ziziphus nummularia* (Abdel-Dayem et al., 2017).

Familia COCCINELLIDAE Latreille, 1807

***Coccinella septempunctata* Linnaeus, 1758**

One specimen was collected in station R2. This ladybird has an extremely large distribution and occupies the whole Palaearctic region, extending into the Afrotropical, Nearctic and Oriental regions (Kovář, 2007). In Iran it is reported from almost every province but there is no data from Lut desert according to Borumand (2000).

Familia SCARABAEIDAE Latreille, 1802

***Clipadoretus* cf. *persicus* Ohaus, 1941 (Fig. 7)**

Two specimens were collected at light at station R3. Machatschke (1965) described *dentatus* from Nermashir. Later, Petrovitz (1967) described *quadridentatus* from Pakistan, Quetta, which differs at least by male genitalia, 10-jointed antennae and the presence of a fronto-clypeal suture and was tentatively placed in this genus. In fact, an acute identification is postponed to a modern revision.

Familia APHODIIDAE Leach, 1815

***Mendidius beluchistanicus* (Petrovitz, 1962)**

One specimen was collected at light at station R3. This is a deserticolous species described from Iran (Belouchistan). It seems that no other observations were made in Iran or elsewhere before its discovery in the eastern provinces of Saudi Arabia (Pittino, 1984). This species is also reported

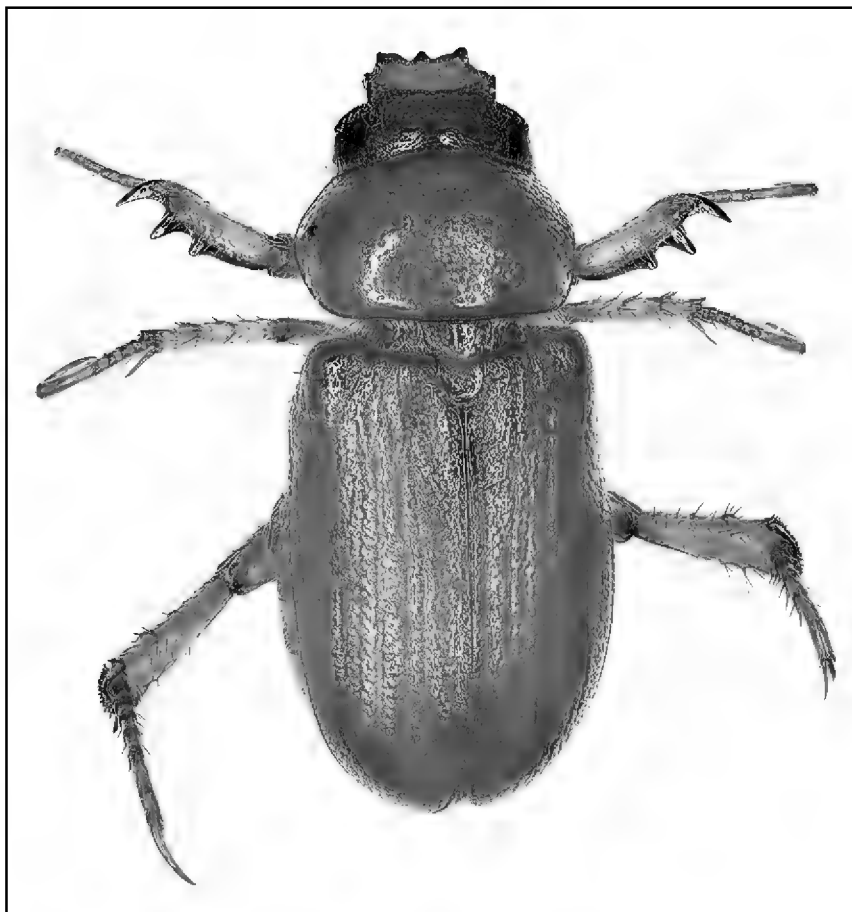


Figure 7. *Clipadoretus* cf. *persicus*
Ohaus, 1941, from site R3.

from Iraq by Dellacasa & Dellacasa (2006). Its distribution area is possibly much wider because it can be confused with a very similar species, *Mendidius laevicollis* (Harold, 1866)

Ordo HETEROPTERA Latreille, 1810
Familia PENTATOMIDAE Leach, 1815

***Brachynema germarii* (Kolenati, 1846)**

One specimen was found at station R3. It is attracted by light and has already been reported from Iran (Ribes & Pagola-Carte, 2013). In France it is a very rare species occurring only in the South, more abundant in North Africa, Egypt, Israël, Jordan, Syria, and reaches Mongolia and China to the East. This halophytic species is often found in xeric localities, on various plants growing on salty soils: *Zygophyllum*, *Anabasis*, *Alhagi*, *Artemisia*, *Suaeda*, *Beta*.

***Chroantha ornatula* (Herrich-Schaeffer, 1842)**

One specimen was found at station R3. Widespread in North Africa, Arabian Peninsula and already reported from Iran (Ribes & Pagola-Carte, 2013). This species lives mainly on *Suaeda* but also on *Salsola* and *Zygophyllum*.

Familia LYGAEIDAE Schilling, 1829

***Cosmopleurus fulvipes* (Dallas, 1852)**

One specimen was found at station R3. This species is widespread in the desertic regions of North Africa, and in the Saharo-Sindian deserts, eastwards to Pakistan. It is already reported from Iran (Péricart, 1998a). *Cosmopleurus fulvipes* is a xerophilous and deserticolous species. Its biology is poorly known but this Lygaeidae is probably polyphagous, with a predilection for Asclepiadiaceae such as *Pergularia tomentosa*.

***Emblethis gracilicornis* Puton, 1883**

One specimen was found at station R3. As with the previous species, *Emblethis gracilicornis* is an Eremian element that occupies the North African and Middle Eastern deserts in the East, present in Iran (Péricart, 1998b) and reaching tropical Africa to the south. This is a polyphagous, granivorous and terricolous species.

Familia CYDNIDAE Billberg, 1820

Byrsinus nigroscutellatus (Montandon, 1900). One specimen was found at station R3. This species is reported from Algeria, Chad, Egypt, Lybia, Mauritania (Lis, 2003), and was also recently reported from Iran (Ghahari et al., 2009). Many cydnids are burrowing Heteroptera, living on soft soils, and are certainly phytophagous and radicicolous. The biology of *Byrsinus nigroscutellatus* seems not known.

DISCUSSION: BIOGEOGRAPHICAL AND ECOLOGICAL IMPLICATIONS

An unexpectedly diverse arthropod fauna

The most outstanding finding of this study is that there is very few common taxa between the recently collected assemblage and the assemblage collected during the Franco-Iranian mission in the late 1960's by Théodore Monod (Pierre, 1974). The following species were collected during both expeditions: *Leiopteroblatta monodi*, the endemic sand dweller cockroach, was collected by Monod at

Rig-é-Lut (Rig-e Yalan); *Sphingonotus* sp. could correspond to *Sphingonotus* (*Sphingonotus*) *theodori iranicus* (Mistshenko, 1936), the sole *Sphingonotus* species reported from Lut by Pierre (1970); *Calosoma* (*Caminara*) *olivieri* was reported from many localities by Pierre (1970); *Aeoloides grisescens* collected in 2014 may corresponds to *Aeoloides* sp. reported by Pierre (1970) from Baloutchab and Shahdad river; concerning the *Heteroptera* *Cosmopleurus fulvipes* was already reported by Pierre (1970) from “Dunes au N.E. de Baloutchab”. The total absence of Tenebrionidae in our material from 2014 is really unexpected since this family is the dominant beetle group in desertic regions (Dajoz, 2002).

Pierre (1970) reports about 60 taxa from the Lut Desert, later Pierre (1974) provides a more complete list concerning the groups Tenebrionidae and Scarabaeoidea only, including 26 taxa in total. The latter collection studied and published by Franklin Pierre dates to March 1970 (Pierre, 1974). Although the insect collection presented in this study was not performed in a systematic way and postdated, by about one month, the Monod's collection date, it yielded 15 taxa belonging to 4 insect orders. This taxonomic difference can be explained in several different ways. It can be due to the one-month difference in collection dates and a reflection of the different timing of the life cycles of taxa belonging to the two assemblages. However, it can also be due to different weather conditions in 1970 and 2014 winter-spring transition. The other possibility is that the taxonomic diversity of insect fauna of Lut is much more significant than expected from a subtropical hyperdesertic area. Pierre (1970) considers that the ca. 60 taxa collected during the Franco-Iranian mission of 1969 corresponds to the 2/3 of the total insect fauna of the Lut region. Our results suggest that these figures may be clearly underestimated. All the above facts highlight the necessity for well-organized entomological expeditions to unravel the cryptic insect biodiversity of Lut Desert.

“Aphytic” but not “abiotic”

By far the richest arthropod assemblage was encountered at station R3, mainly around the halogen lights: in total 9 species were observed, including 4 species of *Coleoptera* and 5 species of *Het-*

eroptera. This is especially interesting because this region is thought to represent the hottest spots on Earth, and is totally devoid of phanerogamic vegetation.

The high diversity of insect fauna of Rig-e Yalan and Central Hammada raises the question of the nature of food web in this extremely hot and dry desert. In the absence of any plant life in central Lut Desert especially in Kalut and Central Hammada, it is not clear what the source of primary production is. Grasshoppers constitute the most abundant herbivorous insects that consume foliage in most semi-arid and arid environments of the world and commonly prefer feeding on annual rather than perennial shrubs. However, in severe climatic conditions they may shift their feeding strategy to perennials with higher quantities of deterrents and toxins in order to keep their water balance (Otte & Joern, 1977). We did not observe any source of primary production in the central and eastern Lut Desert. However, grasshoppers (*Sphingonotus* sp.) were observed feeding on dead bodies of migrating gulls, probably *Larus cachinnans* which is widespread in the Middle East (Porter & Aspinall, 2010) (Fig. 8). Ants form the dominant surface-active arthropod faunas of the arid and semi-arid regions. Their colonies have been observed even in areas with sparse or practically no vegetation (Whitford & Wade, 2002). However, no species of ant was observed during our expeditions to Lut. Ground-dwelling beetles and particularly the detritivorous Tenebrionidae are the next most abundant groups of arthropods in these environments. According to Crawford (1988) their abundance in sand dunes has been attributed to the specific characteristics of sand dunes. The high porosity of sands permits water infiltration and accumulation in a shallow depth below surface and the low heat conductivity causes rapid temperature gradients creating survivable habitats for these insects. Abundance of these detritivorous insects can also be explained partly by trapping of wind-blown organic detritus from other areas. It is possible that the wind-blown detritus from peripheric vegetation-bearing mountain and desert steppes surrounding the Lut Desert provide the required primary biomass for the survival of the Lut insects and vertebrate fauna. Part of these organic detritus can also come from the very sparse vegetation found in the interior parts



Figure 8. *Sphingonotus* sp. feeding on the dead body of a migrating bird, *Larus* cf. *cachinnans*.

of Rig-e Yalan.

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the precursors to later intensive ecological expeditions organized by Prof. H. Akhane in 2015 (see Stone, 2016).

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The first occurrence of *Cycloachelous granulatus* (H. Milne Edwards, 1834) (Decapoda Portunidae) from Klah Island, Indonesia

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ABSTRACT

This article reported the first occurrence of *Cycloachelous granulatus* (H. Milne Edwards, 1834) (Decapoda Portunidae) from Klah Island (close to Sabang Island), Aceh Province. Two specimens were collected in intertidal zone of Klah beach, on June 2018. Our findings contribute to Indonesian Biodiversity Database and could be used as the basis to develop faunal knowledge such as study on taxonomic, biogeographic, evolutionary or conservation.

KEY WORDS

Distribution; sea crab; systematic; western Indonesia.

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INTRODUCTION

Indonesia is one of the biodiversity hotspots in the world, due to the high variation of the living organisms. Indonesia is located between two oceans, namely the Pacific Ocean and the Indian Ocean. One of the reasons of the high variation is due to the flow that comes from the Pacific Ocean to the Indian Ocean which distributes the marine biota (Wyrski, 1961). One of the marine biota is sea crabs which belong to infraorder Anomura and Brachyura.

Cycloachelous granulatus (H. Milne Edwards, 1834) (Decapoda Portunidae) is a brachyuran, which is distributed in Madagascar, Red Sea, and Hawaii, including Japan, Australia, Fiji and Samoa (Stephenson, 1972), Northern Arabian Sea (Tirmidzi & Ghani, 1981), Botany Bay (1993), South

Somalia-Kenya (2000). In Indonesia, it was reported in the eastern part, such as Ambon (Serene et al., 1976), Ternate (Apel & Spiridonov 1998), Tikus Island (Anggraeni et al., 2015), and Sundak Beach (Sukmaningrum et al., 2018). However, reports from western Indonesia have not been found. Therefore, this article reports the occurrence of the species from Klah Island, Aceh province (Indonesia).

MATERIAL AND METHODS

Two specimens of *Cycloachelous granulatus* were captured by hand net in the intertidal zone on 29.VI.2018 in Klah Island, Aceh province (Indonesia) (Fig. 1). The specimens were preserved in 70% alcohol for a day, then substituted in 96% alcohol

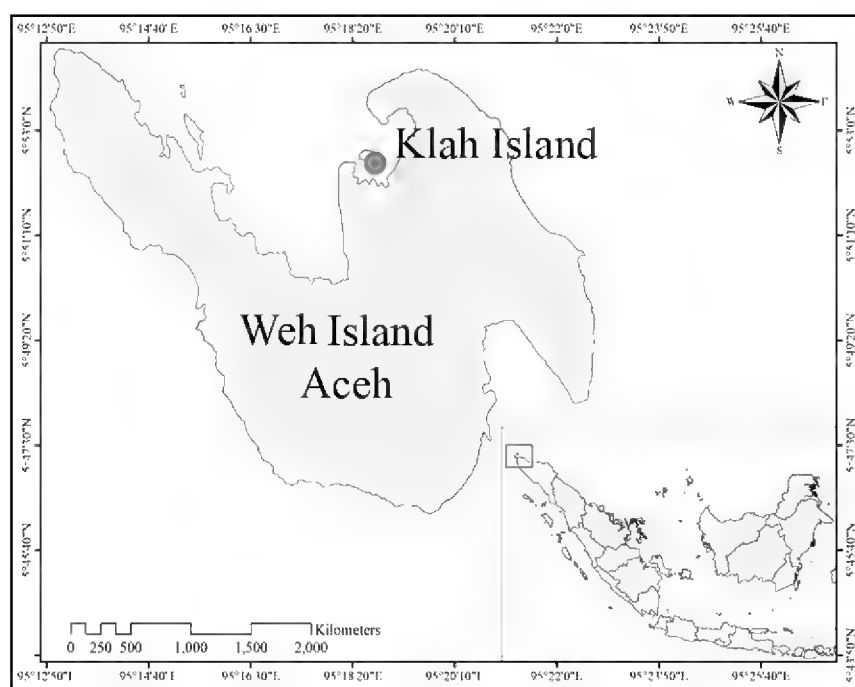


Figure 1. Map of study area.

for storage and deposited at the Laboratory of Bio-systematic and Animals Ecology. The specimens were identified following Stephenson & Campbell (1958), Tirmizi & Ghani (1981) and Vannini & Innocenti (2000).

ABBREVIATIONS. CL: Carapace Length. CW: Carapace Width.

RESULTS

Systematics

Classis MALACOSTRACA Latreille, 1802
Ordo DECAPODA Latreille, 1802
Infraordo BRACHYURA Linnaeus, 1758
Superfamilia PORTUNOIDEA Rafinesque, 1815
Familia PORTUNIDAE Rafinesque, 1815
Subfamilia CARUPINAE Paulson, 1875
Genus *Cycloachelous* Ward, 1942

Cycloachelous granulatus (H. Milne Edwards, 1834) Figs. 2, 3

Achelous granulatus (H. Milne Edwards, 1834)

Portunus (Achelous) granulatus (H. Milne Edwards, 1834)

EXAMINED MATERIAL. Indonesia. 2 males, CW = 17.6 mm and 25 mm; CL = 12.1 mm and 16.8 mm]; Sumatera, Klah Island; 5°52.4189'N, 95°18.7411'E; 0 m a.s.l., 29 jun. 2018; Hafiz "leg."; intertidal zone; GenBank: LC521922. Spe-

cimens are deposited in the Laboratory of Biology Departement, IPB University with collection number S36.

DESCRIPTION. Males. In front region, the median lobe is the lowest, and the submedian/lateral lobe is the highest. The carapace is circular, and most of its surface is covered by granules, the sharpness and measure of anterolateral teeth is almost the same.

Front: the median lobe is divided into two lobes with a shallow indentation. The tooth between the median lobe and the inner supraorbital lobe is the highest tooth in the frontal region of carapace, whereas the lowest tooth is the median tooth.

Carapace: The size is wide. The posterior border is rounded, and its surface has granules. The cardiac region is in the middle vertically, and the posterolateral area is the most extensive. The sharpness and measure of the anterolateral teeth are almost the same, however, the widest is the first spine, and the sharpest is the last one.

Chelipeds: long and slim. The inner surface of manus/palm has granules and small pit, the upper surface hand is hirsute. The cheliped has two spines of posterior of manus, four spines on the anterior border of merus, three spines of the carpus, and one spine on posterior of manus.

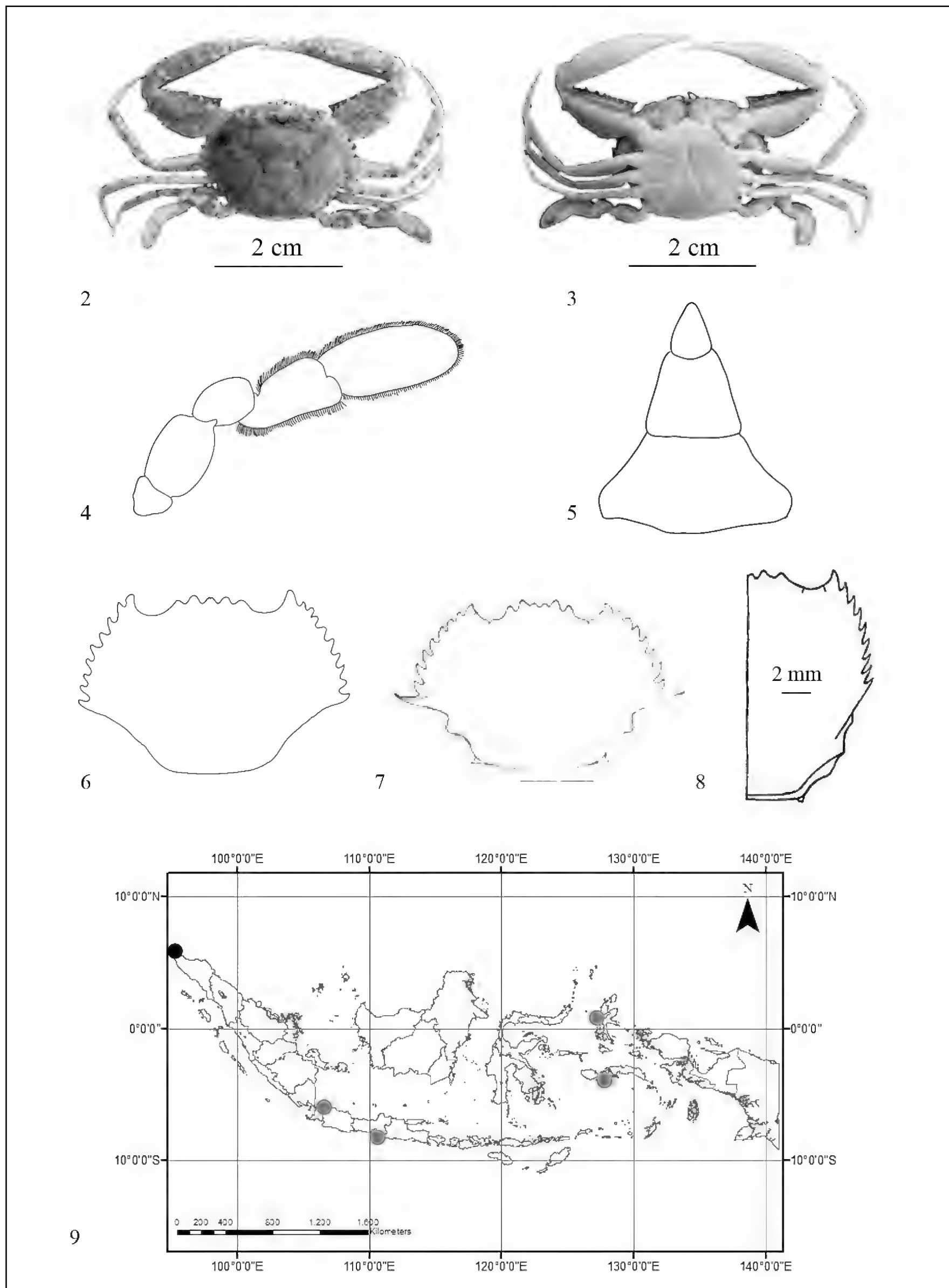
Fifth leg: has hairs in the outside edge of the propodus and dactylus (Fig. 4).

Male abdomen: the penultimate is more than two times breadth of ultimate segment (Fig. 5).

DISCUSSION

Cycloachelous granulatus specimens were collected in intertidal zone which was inundated by water at 05.30 p.m. at local time. The habitat characterised by mix of white and black sands, muddy, coral reef, and rock. The species has been reported found in nine meters under the water depth (Vannini & Innocenti, 2000) and also found in 120 meters under the water depth (Shantanam, 2018). Based on these phenomena, we believe that the species has a good adaptability to the water pressure, salinity, oxygen, temperature, and nutrient.

Mostly, the species is reported from the Pacific Ocean, such as Philippines, Melanesia, Marianas, Marshalls, Samoa, Hawaii and Toamotus (Stephenson & Rees, 1967). It was assumed that the expan-



Figures 2, 3. *Cycloachelous granulatus*: dorsal (Fig. 2) and ventral view (Fig. 3). Figure 4. *Cycloachelous granulatus* fifth leg. Figure 5. Same as above, abdomen. Figure 6–8. Carapace of *C. granulatus* (Fig. 6), *Portunus orbitosinus* (Fig. 7), and *P. orbicularis* (Fig. 8). Figure 9. Distribution of *C. granulatus* in Indonesia (red dots: previous study; black dot: this study).

N°	Characteres	<i>C. granulatus</i>	<i>P. orbitosinus</i>	<i>P. orbicularis</i>	References
1	Carapace	Carapace uniformly granulate, without smooth zones between the granule clusters	Lobus in central are larger than in <i>C. granulatus</i>	Data is not available	Vannini & Innocenti, 2000; Stephenson & Campbell, 1958
2	Male abdominal	The sixth male abdominal (penultimate) segment with lesser convex sides and without median swelling; the penultimate is two times the breadth of the ultimate segment (this study)	Penultimate segment swollen, i.e. with extremely convex borders, maximum breadth nearly 3 times the breadth of the ultimate segment.	Data is not available	Vannini & Innocenti, 2000; Stephenson & Campbell, 1958
3	Anterolateral teeth	Almost equal in measure and sharpness, the first the broadest, the fourth usually the smallest, and the sharpest is the last	Approximately equal size and all sharp, the first the broadest, the second was the smallest, the last slightly the most protruding	The nine teeth of anterolateral border diminish in size from front to back; last anterolateral spine the smallest	Edmondson, 1954; Stephenson & Campbell, 1958; Shantanam, 2018;
4	The third maxilliped	The hirsute covering of the ischium of the third maxillipeds, sometimes the hair are long and dense, and sometimes short	Antero-external angle of merus produced acutely in a lateral direction.	Data is not available	Stephenson 1972; Stephenson & Campbell, 1958
5	Male Pleopod	First male pleopod stout, with widely flared tip	The outer side of the tip with no armature and the inner side with 3 or 4 microscopic spinules	The structure of male pleopod is very different from <i>C. granulatus</i>	Stephenson & Campbell, 1958; Vannini & Innocenti, 2000
6	Color	Pale, with darker lined dots	Variable from pink to yellow	Dark brown mottled on pale creamyback round	Vannini & Innocenti, 2000

Table 1. The morphological differences between *Cycloachelous granulatus*, *Portunus orbitosinus* and *P. orbicularis*.

sion of *C. granulatus* to the Indian Ocean from the Pacific Ocean through Indonesian waters was caused by the water flow which originated from Pacific to Indian Ocean (Wyrтки, 1961) during the larva phase (Anger, 2001). Data about the stage of *C. granulatus* larvae is not available, but the stage from another species from genus *Portunus* Weber, 1795 such as *P. spinicarpus* (Stimpson, 1871) which has a duration of its larvae stage about 38–46 days long (Bookhout & Costlow, 1974), could be assumed. The long-time period of the larval stage might make the *C. granulatus* disperse widely in the waters.

The carapace sharp of *C. granulatus* is similar to *P. orbitosinus* Rathbun, 1911 (Vannini & Inno-

centi, 2000; Shantanam, 2018; Stephenson, 1972) and also with *P. orbicularis* (Richters, 1880) (Shantanam, 2018) (Figs. 6–8). The differences between those organism will be presented in Table 1.

Distribution of *C. granulatus* in Indonesia is showed in figure 9.

This article contributes to the Indonesian Biodiversity Database and could be used as the basis for the future study on taxonomic, biogeographic, evolutionary or conservation.

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Where two giants meet: the first records of *Sphodromantis viridis* in Sicily and Greece and the spread in Europe of *Hierodula tenuidentata* (Insecta Mantoidea) show new crossroads of mantids in the Mediterranean

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ABSTRACT

The first presence records of the Giant African Mantis *Sphodromantis viridis* (Forskål, 1775) (Insecta Mantoidea) are reported for Sicily and Greece, with new evidences on the human-mediated spreading of this species in the Mediterranean area. In Greece, *Sphodromantis viridis* meets the distribution of the Giant Asian Mantis *Hierodula tenuidentata* (Saussure, 1869), and these two mantids have been recorded together in the same locality. Some single records from France and Corsica also open the possible expansion of this species in more northern regions. These different spreading dynamics, taking place in the Mediterranean area, in a fast-evolving scenario, are here discussed.

KEY WORDS

Giant mantises, distribution, new records, human impact, invasive species.

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INTRODUCTION

During the last few years, the mantid populations in the Euro-Mediterranean area have significantly changed. From one side the commercial routes from Asia to Europe have been used by at least two species of Giant Asian Mantids: *Hierodula tenuidentata* (Saussure, 1869) and *H. patellifera* (Serville, 1839) to spread in Europe (Battiston et al., 2018, 2020; Moulin, 2020, Schwarz & Ehrmann, 2018) creating well-settled populations in different countries. If *H. patellifera* appears now well settled in northern Italy and Provence, *H. tenuidentata* is spreading fast in the Balkans reaching most of the Greek islands and northern Italy. Other smaller populations or single individuals of other mantid species have been recorded in Europe

in a fast-changing scenario (Schwarz & Ehrmann, 2018).

The Giant African Mantis *Sphodromantis viridis* (Forskål, 1775) is also spreading in the Mediterranean area with particularly interesting dynamics. This xerothermophilous but very adaptable species is widely distributed from the sub-Saharan regions of northern Africa to the Middle East. Its presence in Europe has been limited in historical times to Southern Spain with the western subspecies *S. viridis vischeri* Werner, 1933. In 2004, this mantid appears in the Balearic island of Mallorca (Cantelles & Alomar, 2006) and later in Sardinia: first in a small island in the northern archipelago and then in the mainland with many different observations from North to South (Battiston et al., 2017, 2019). From a first morphological analysis (Battiston et al.,

2017) these populations seem to be linked to the Iberic subspecies, while the presence of this species in some islands in the southern Mediterranean area is probably related to the North African subspecies *S. viridis barbara* and *S. viridis viridis* as supposed by La Greca (1966). Despite its wide distribution this species is a poorly known insect and its dynamics are still far to be well understood, but while *Hierodula* seems to follow more global commercial routes from East to West, *Sphodromantis* seems to reflect a more local-Mediterranean dynamic, too fast and sudden to be natural but opportunistic if artificial. Thus far, these two genera, very similar in many aspects of their biology, have not yet met each other, but some new records here presented may confirm the first contact.

MATERIAL AND METHODS

Literature records have been examined together with digital databases (iNaturalist, GBIF) and social media. In this case, some records previously identified as *Hierodula* or *Mantis religiosa* (Linnaeus 1785). The records and specimens from Sicily have been observed and collected during random samplings. Five site inspections have been made in the collecting locality to verify its presence and evaluate its density. The records from Greece have been identified from several detailed photographs sent by the observers.

RESULTS

Sphodromantis viridis (Forskål, 1775) new presence records (Figs. 1, 2): Italy. Sicily, Catania (37°32'30.6"N 15°05'00.6"E), 19.X.2019, 1 adult female, 2 oothecae. Urban park, degraded garrigue environment.

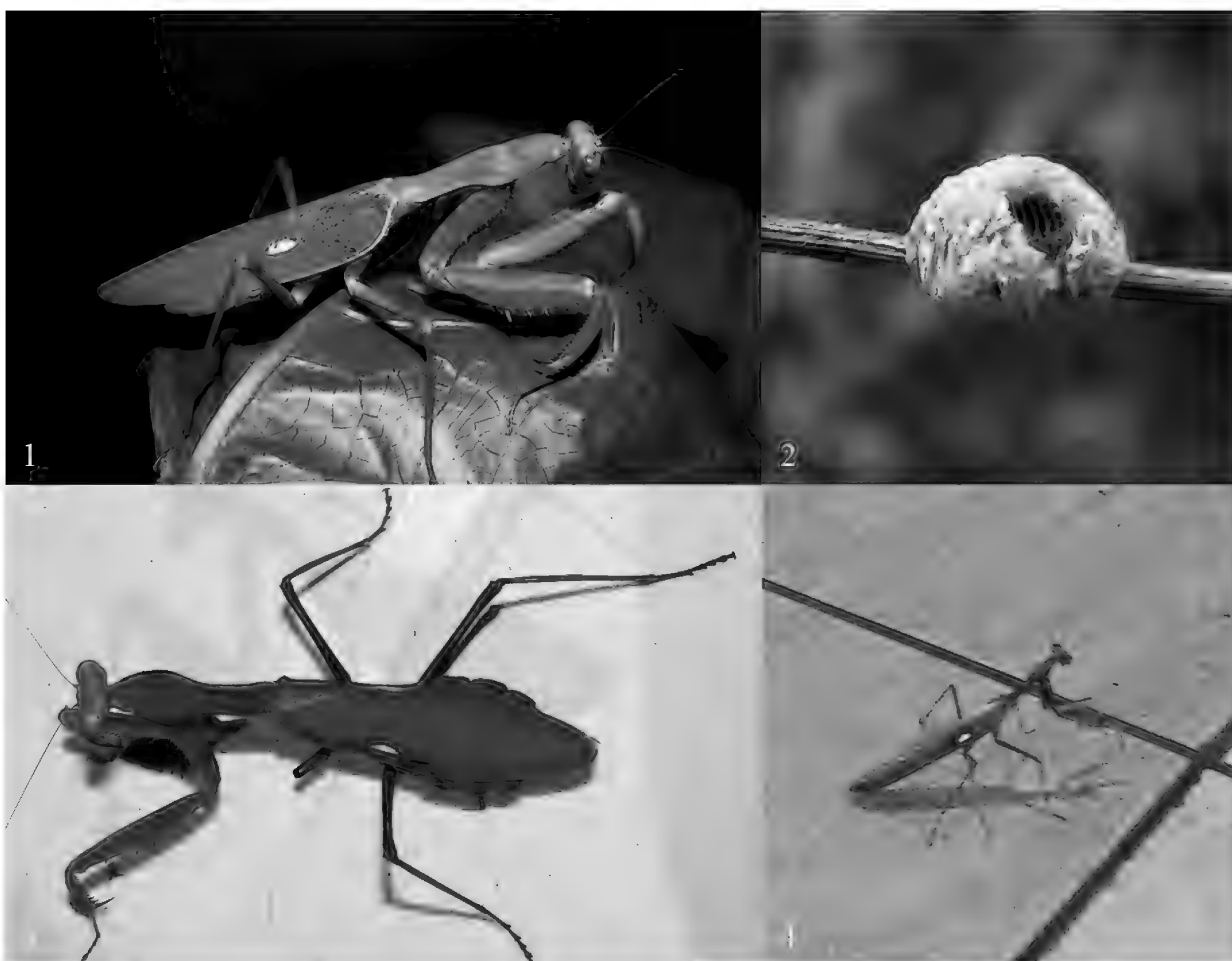
Greece (Figs. 3, 4). Patronikoleika (37°42'23.3"N 21°19'16.7"E), 29.IX.2019, Murru obs., 1 adult male; touristic beach, residential environment. Glifada (37°53'03.4"N 23°44'48.7"E), 12.X.2019, Zafeiriou obs, 1 adult female; urban environment. Alsoupoli (38°01'56.7"N 23°46'45.0"E), 29.VIII.2020, Vasilis obs, 1 sub-adult; urban environment.

France. Biscarrosse (44°27'54.5"N 1°13'49.7"W) 12.XI.2018. iNaturalist record: 18353062, 1 adult female. Coastal areas near touristic residences.

Corsica, Ile Rousse (42°38'02.4"N 8°56'15.1"E), 21.10.19. iNaturalist record: 34697875, 1 adult male. Touristic beach, residential environment.

DISCUSSION

After the first update on its distribution (Battiston et al., 2017), *S. viridis* confirmed a tendency to spread quickly in the Mediterranean basin. This species seems to be very adaptable to different environments even to very anthropized ones. Its presence in urban or residential environments and the speed of the spreading over so distant localities, especially in the islands, support the hypothesis of human-mediated transport at the global level. The distribution limits of this species inside the Mediterranean Climate Domain seem to be still respected, even if the distribution is expanding to the north. The presence of *S. viridis* in Sicily, where it has never been recorded before, is attested by the presence of a gravid female and two oothecae, one of which clearly older than 2019, with deterioration, exfoliation and damage. The mantid individual was found in the small natural reserve Timpa di Leucatia, on the border of a wetland near a degraded garigue environment (where the oothecae were found), surrounded by the large urban area of Catania. Besides the small natural spot, the area is degraded and very anthropized without ecological corridors with other natural areas and can be defined as an urban park. We can exclude the arrival of this specie as a natural expansion of its distribution in the wild. The presence of stable continental populations in Europe, outside the Iberian Peninsula, still needs to be verified from the few single specimens here recorded. In France, this species should be still considered as occasional and vagrant, but the single records here reported open the possibility of an expansion of this adaptable species in more northern regions that should be investigated. A stable presence seems now to occur in Greece, where the records of both males and females in different years and localities suggest, with more confidence, the possible existence of small populations in the mainland in Attica and with possible records also in the islands: the Peloponnese, and a juvenile of cf. *Sphodromantis* reported in Crete (iNat: 60785200, dated 2014). The area of Athens with the records of Glifada and Alsoupoli,



Figures 1, 2. *Sphodromantis viridis* from Italy: adult female (Fig. 1) and ootheca (Fig. 2), photos D. Borgese. Figures 3, 4. *Sphodromantis viridis* from Greece: adult female from Glifada (Fig. 3, photo S. Zafeiriou) and male from Patronikoleika (Fig. 4, photo A. Murru).

appears interesting because iNaturalist reports also many presence record of *Hierodula* other than *Sphodromantis*. In the same locality of Patronikoleika, in the Peloponnese, *Mantis religiosa* is also reported (iNat: 31465138).

The presence of *Sphodromantis* here sets up the first meeting point with *Hierodula* and their interaction should be evaluated in the near future. This should be evaluated also in Provence where this latter genus is present with the species *H. patellifera* Serville 1839 (Moulin, 2020). This appears to be a good time for these mantids to spread and increase their distribution, but while *Hierodula* arrived from far eastern countries, *Sphodromantis* was already present in the Mediterranean, so why now? Mediterranean Climate Domain is currently evolving and shifting together with the Arid Climate Domain. Projected changes in climate param-

eters (Barredo et al., 2018) indicate a transition towards hotter and drier conditions and, consequently, the establishment and spread of invasive alien species (Hellmann et al., 2008). *Sphodromantis* with its confidence with anthropized environments and human-mediated transport is here an adaptable and opportunistic species that should be monitored in the future, especially in its impacts on the local ecosystems and on other native or alien mantids species.

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